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The Transmission of "Rosette" Disease of Peanuts by an Aphis

Messrs. H. H. Storey and A. M. Bottomley,* of South Africa, have demonstrated that the disease in the ground nut or peanut (*Arachis hypogea*, L.), known in South Africa as "rosette", is transmitted by *Aphis leguminosae* Theo. This disease belongs to the virus group, to which the mosaic of sugar cane also belongs. These two workers believe "rosette" to be identical with "Krauselkrankheit" of Zimmermann in East Africa, with the "Krulziekte" of Rutgers in Java and with the bunching or "clumping" in West Africa and India. About nine species of Homoptera which feed upon peanut were experimented with, but all except *Aphis leguminosae* gave negative results.

This work has interest for us: first, on account of our work with sugar cane "mosaic" and, second, demonstrating how important it is to keep out of Hawaii all insects which may be capable of conveying plant diseases.

F. M.

* Nature, No. 2907, Vol. 116, p. 97, July 18, 1925.

Cut-back vs. Not-cut-back Experiment

By H. B. Penhallow

This experiment was carried out by the plantation in Field 92 with H 109 ratoon cane under the usual plantation conditions to determine the effect of not cutting back, as cutting back has been considered necessary at Wailuku, due to the prevalence of heavy tasseling there in all varieties of cane. Prior to the present experiment various small plots have been under observation, indicating that cutting back might be dispensed with under certain conditions. The present experiment, carried out on a sufficiently large area to give more conclusive results, shows a definite gain from not cutting back in H 109 ratoons.

The area involved in this experiment covered 71.30 acres of H 109 ratoons, of which 38.36 acres were cut-back and the remainder, 32.94 acres, not-cut-back. The plots consisted of 10 alternating not-cut-back level ditches with 9 cut-back ditches, thus sufficient repetitions were assured.

The field was harvested during February and March, 1925. The cane from the various plots was carefully weighed and sampled under special supervision.

The previous crop was harvested during the months of March and April, 1923, and cutting back took place June 23 to 27.

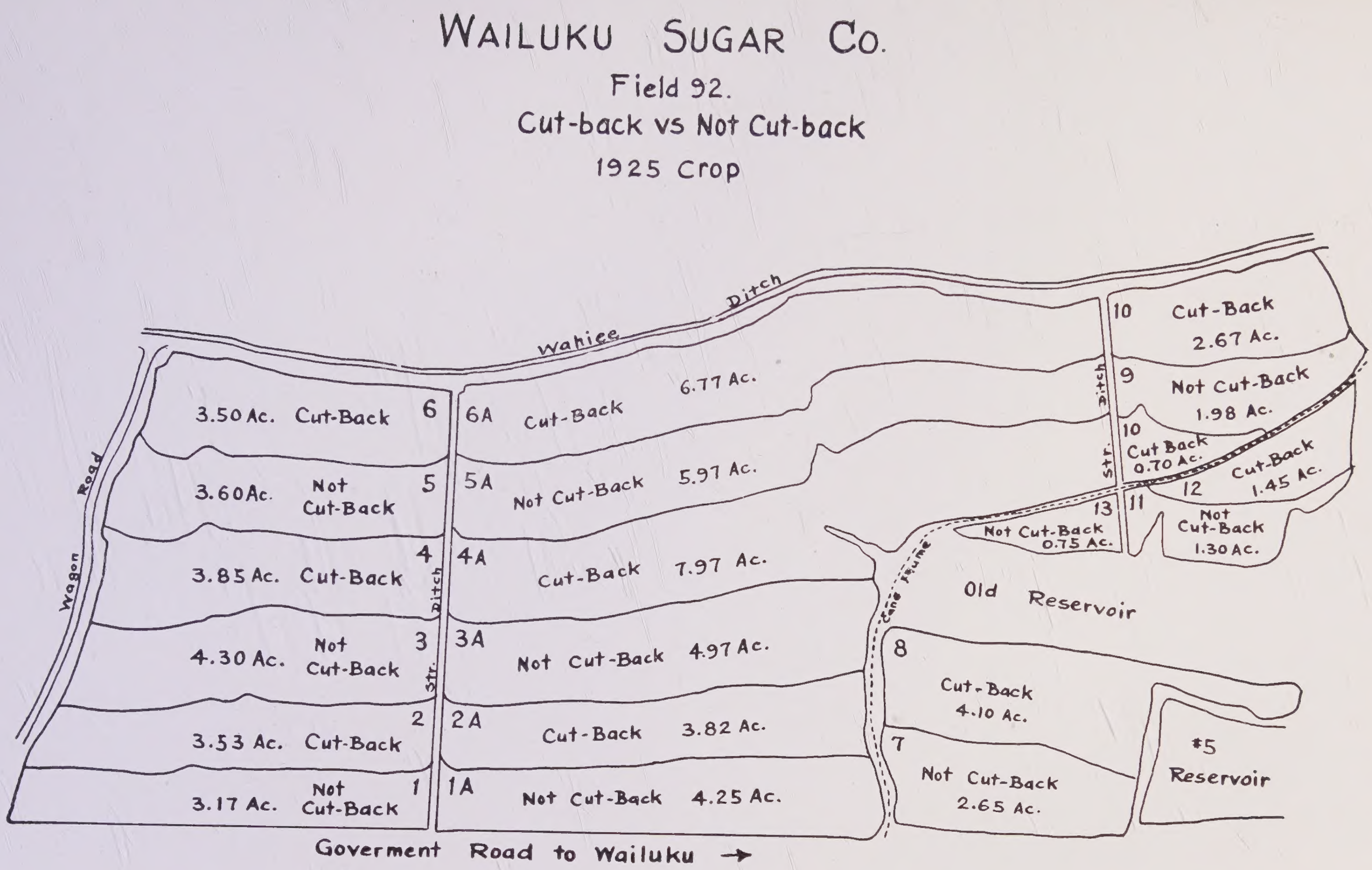
Fertilization consisted of an application of B-7 at the rate of 1,000 pounds per acre in the latter part of August and an application of 170 pounds of nitrogen from nitrate of soda in the latter part of November, 1923.

The cut-back ditches required three more weedings than did the not-cut-back ditches.

In regard to tasseling, the following notes were made on or about the 8th of December, 1923: "In Field 92 there is very little tasseling (only one here and there) in the first ditch above the Government Road, which showed most dryness from lack of water several months ago, and no tasseling in the cut-back ditches. The other not-cut-back ditches have more tassels, mostly along the level ditches, straight ditches and watercourses. If a tassel count should be taken in the spots where there is heaviest tasseling, between 10 per cent and 15 per cent tasseling would be evident."

That heavy tasseling did not take place in the not-cut-back ditches was further substantiated at harvesting by the fact that not a great number of lalas were to be found. Stalks which did have lalas were found mostly along level ditches and watercourses where, as mentioned above, the most tasseling took place. Stalks with all the way from 1 to 4 lalas were found, the average running about 2. Average length of lalas was about 5 feet while the main stalk ran from 4½ to 5 feet.

As can be seen from a study of the results obtained, the not-cut-back ditches outyielded the cut-back ditches in tons cane per acre and also gave a better quality


WAILUKU SUGAR CO.
Field 92.
Cut-back vs Not Cut-back
1925 Crop
Wahiee Ditch
Wagon Road
6 3.50 Ac. Cut-Back
5 3.60 Ac. Not Cut-Back
4 3.85 Ac. Cut-Back
3 4.30 Ac. Not Cut-Back
2 3.53 Ac. Cut-Back
1 3.17 Ac. Not Cut-Back
Ditch
Str.
6A Cut-Back 6.77 Ac.
5A Not Cut-Back 5.97 Ac.
4A Cut-Back 7.97 Ac.
3A Not Cut-Back 4.97 Ac.
2A Cut-Back 3.82 Ac.
1A Not Cut-Back 4.25 Ac.
10 Cut-Back 2.67 Ac.
9 Not Cut-Back 1.98 Ac.
10 Cut Back 0.70 Ac.
12 Cut-Back 1.45 Ac.
11 Not Cut-Back 1.30 Ac.
13 Not Cut-Back 0.75 Ac.
Cane flume
Old Reservoir
8 Cut-Back 4.10 Ac.
7 Not Cut-Back 2.65 Ac.
#5 Reservoir
Goverment Road to Wailuku →

ratio. This is possibly due to the extra period of growth in the not-cut-back ditches and also the cane in them being more mature.

A similar experiment is to be harvested in 1926, in which the not-cut-back area showed 34 per cent tassels by count, which is considerably higher than in the one just harvested.

WAILUKU SUGAR COMPANY

Cut-back vs. Not-cut-back

Field 92—Crop 1925

Ditch No.	N. C. B. or C. B.	Area	Total Tons Cane	Tons Cane per Acre	Q. R.	Tons Sugar per Acre N. C. B.	Tons Sugar per Acre C. B.	Total Tons Sugar N. C. B.	Total Tons Sugar C. B.
1	N. C. B.	3.17	238.475	75.23	6.99	10.76		34.13	
2	C. B.	3.53	245.385	69.51	7.04		9.87		34.85
3	N. C. B.	4.30	307.790	71.58	7.08	10.11		43.48	
4	C. B.	3.85	266.225	69.15	7.21		9.59		36.92
5	N. C. B.	3.60	262.310	72.86	7.08	10.28		37.00	
6	C. B.	3.50	241.325	68.95	7.38		9.34		32.69
1A	N. C. B.	4.25	299.145	70.39	6.81	10.33		43.93	
2A	C. B.	3.82	249.270	65.25	6.98		9.34		35.69
3A	N. C. B.	4.97	327.845	65.96	6.78	9.73		48.37	
4A	C. B.	7.97	500.357	62.78	7.07		8.88		70.83
5A	N. C. B.	5.97	381.331	63.87	6.85	9.32		55.65	
6A	C. B.	6.77	393.923	58.18	7.21		8.07		54.63
7	N. C. B.	2.65	180.435	68.09	6.76	10.07		26.70	
8	C. B.	4.10	245.135	59.79	7.01		8.54		35.04
9	N. C. B.	1.98	118.970	60.08	7.02	8.55		16.93	
10	C. B.	3.37	180.972	53.70	7.16		7.50		25.30
11	N. C. B.	1.30	78.462	60.35	7.38	8.18		10.64	
12	C. B.	1.45	81.765	56.39	7.57		7.45		10.80
13	N. C. B.	.75	43.712	58.28	6.71	8.68		6.51	

SUMMARY

	Area	Total Tons Cane	Tons Cane Per Acre	Q. R.	Sugar
Not-cut-back	32.94	2238.475	67.96	6.92	9.82
Cut-back	38.36	2404.357	62.68	7.14	8.78
In favor of Not-cut-back			5.28		1.04

Blind Seed in H 109

By J. N. P. Webster, Agriculturist, Wailuku Sugar Company

In cutting top seed in fields of H 109 just previous to harvesting, the finding of blind seed, joints without eyes, is of common occurrence. Unless seed cutters watch carefully, out of ten bags cut, from one to two bags of blind seed can be found.

Some seem to think that the appearance of blind seed is a sign that H 109 is going back or degenerating. An instance being found in some seedlings which cannot be extended on account of their not developing eyes. From some observations made recently by the writer this does not seem to be the case.

The field in which the observations were made is laid out in a cut-back vs. not-cut-back experiment, the cane in the not-cut-back ditches being slightly over a year old and tasseling having taken place in November and December, 1924.

A number of primary stalks in a not-cut-back level ditch were examined and it was found that while some had tasseled, others had not. Those that had tasseled were sending forth all the way from 1 to 5 lalas. Fig. 1 shows a group of 4 lalas about 4 months old.

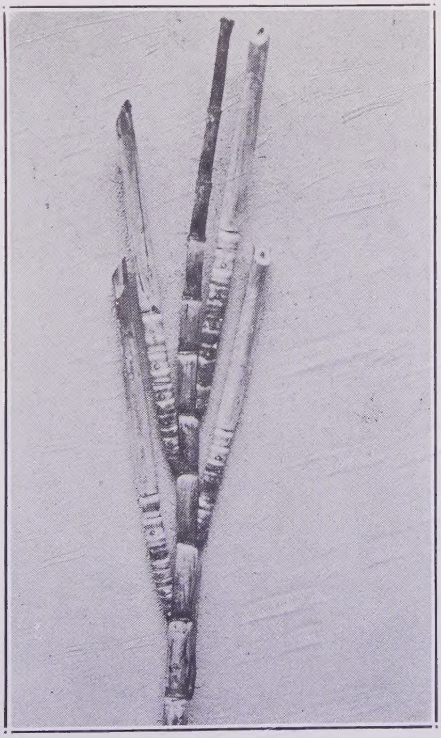


Fig. 1

On the primaries which had not tasseled it was found that, although they appeared to be normal stalks, there was a blind section just beneath the last dry leaf, consisting of anywhere from 5 to 8 nodes. In some instances there were signs of a very small, poorly developed eye, but mostly none at all.

These primaries were practically the same age as those tasseling and the blind sections were noted at a point corresponding, more or less according to the growth, to a section just above the lalas of the tasseled stalks. This last mentioned section is always blind and is a natural characteristic of stalks tasseling.

On all the stalks gone over it was found that above the blind section normal eyes were again being developed. See stalk No. 2 in Fig. 3. Apparently, by some instinct of nature, there is a period of disagreement as to whether a stalk is to reproduce itself by tasseling or not. This causes eyes to stop forming, with the result that we have a blind section covering the period of disagreement.

If it were a case of H 109 going back one would think that with a blind section commenced it would keep on being blind, but this, as pointed out above, is not so.

Furthermore, blind sections have been seen just recently in Lahaina, Striped Mexican, Wailuku No. 5 and Wailuku No. 9, so that this is not a condition peculiar to H 109. That Lahaina develops this feature has been known on Maui for a number of years—probably on other islands as well.

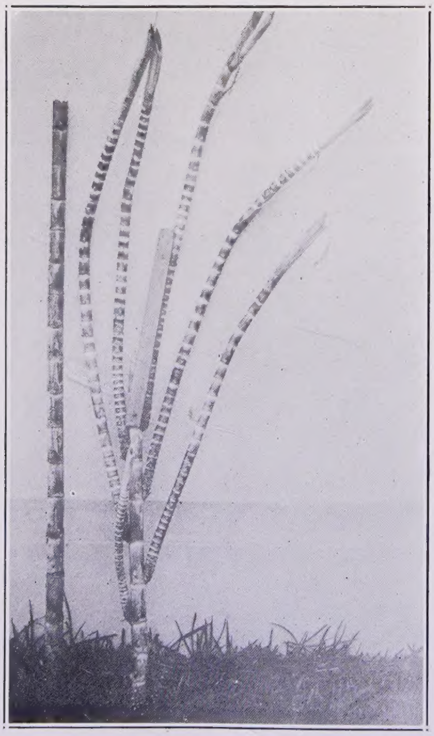


Fig. 2

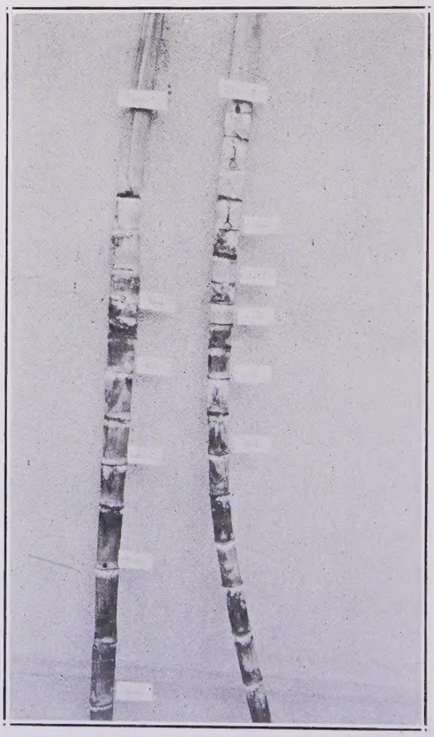


Fig. 3

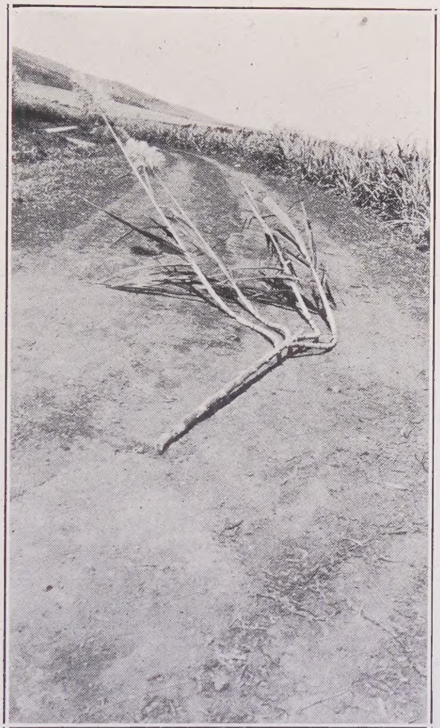


Fig. 4

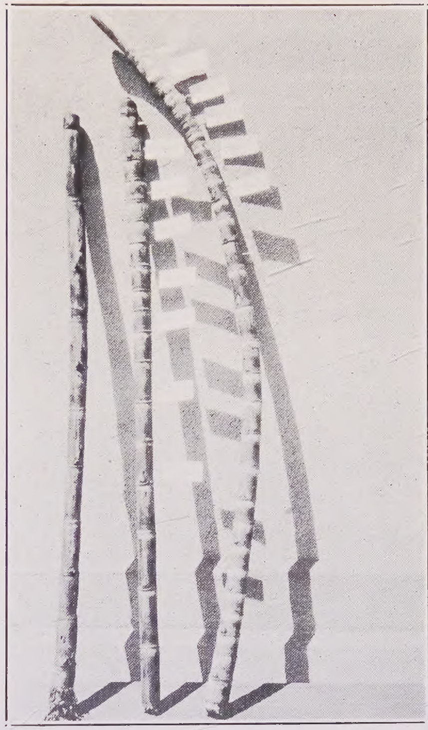


Fig. 5

The abnormal condition noted on stalk No. 1 in Fig. 3 is no doubt the result of a more aggravated period of indecision—whether to tassel or not. Eyes above this part are normal.

In a not-cut-back level ditch of two-year old cane, stalks were found which (1) had not tasseled in two tasseling seasons, (2) others while tasseling in the first season did so in the second, and (3) still others which tasseled in the first season, lalaed, and the lalas tasseled in the second season.

Stalks under (1) above were found to have two blind sections, one about the middle of the stalk and the other at the top. See Fig. 5, which is a whole stalk cut into three pieces. The blind section of the first season can be seen in the middle piece and that of the second season in the piece to the right. Note that all the eyes above the first blind section are normal up to the point representing the tasseling period of the second season, which is blind, then normal eyes again start forming.

Figs. 2 and 4 fall under (3).

The Root System of Sugar Cane

By J. A. Verret

When a sugar cane cutting is planted, as we all know, roots are produced from the root bands at the nodes. The question is often asked as to how long these roots can function, and of what use they are in supplying nourishment to the growing cane.

Very little has been done along this line and we find no reference to it in the literature.

In order to get some information on this, a test was recently started in pots at Makiki.

Seed pieces of the same size were taken, each having three joints. The two end eyes were gouged out of each seed piece.

In two of the pots the cane was allowed to grow normally. These are pots marked A and E, Fig. 1. In the other pots only the roots growing from the seed

Fig. 1

piece were allowed to grow, those coming from the shoots were cut off as they appeared. This was done with sharp scissors so as to cause the least disturbance to the growing plants (Figs. 3 and 4).

The cane remained in the tubs seven months, at which time the stools were dug out and the photographs herewith reproduced were taken.

The tubs were somewhat small and the cane did not make normal growth, but, nevertheless, some very interesting results were obtained.

In the tubs from which the roots of the shoots were cut off, it was found that the roots from the seed piece were alive and functioning. The seed pieces were alive and fresh looking (see A and E in Fig. 2). They were not soured and contained apparently as much sugar as when planted. This shows that, if necessary, the growing cane can obtain its food indirectly. The roots on the seed piece transfer the food material to the seed piece, from which, in turn, it is taken up by the growing cane. This can go on for at least seven months.

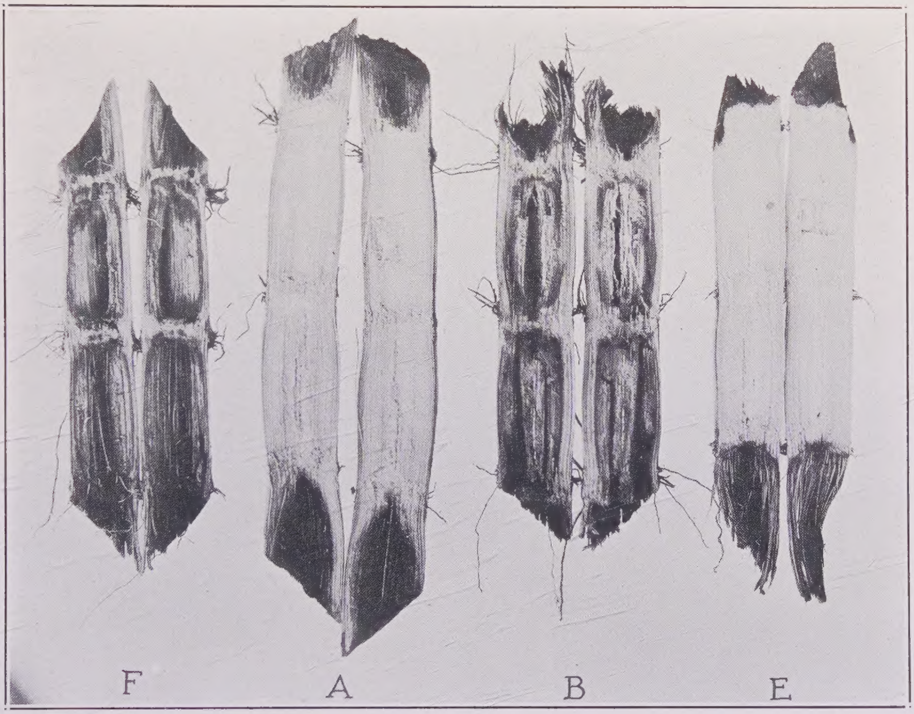


Fig. 2

Conditions were different in the pots in which no roots were trimmed. In these pots the "seed piece" roots were almost all dead, the living ones being from the growing stalks. The seed pieces were shrunken and rotted away. The "seed piece" roots apparently ceased to function as soon as the stalks had roots of their own. When this took place, organisms invaded the seed piece and it began to decay. (See B and F, Fig. 2.)

In the case where the roots were trimmed, the plant was compelled, as previously explained, to obtain its nourishment indirectly through the seed piece. This made the seed piece an integral part of the growing plant and it remained healthy.

From this, it is but a step to the field and some of our practices where we can theorize as to what takes place. When it is necessary to off-bar, when is the

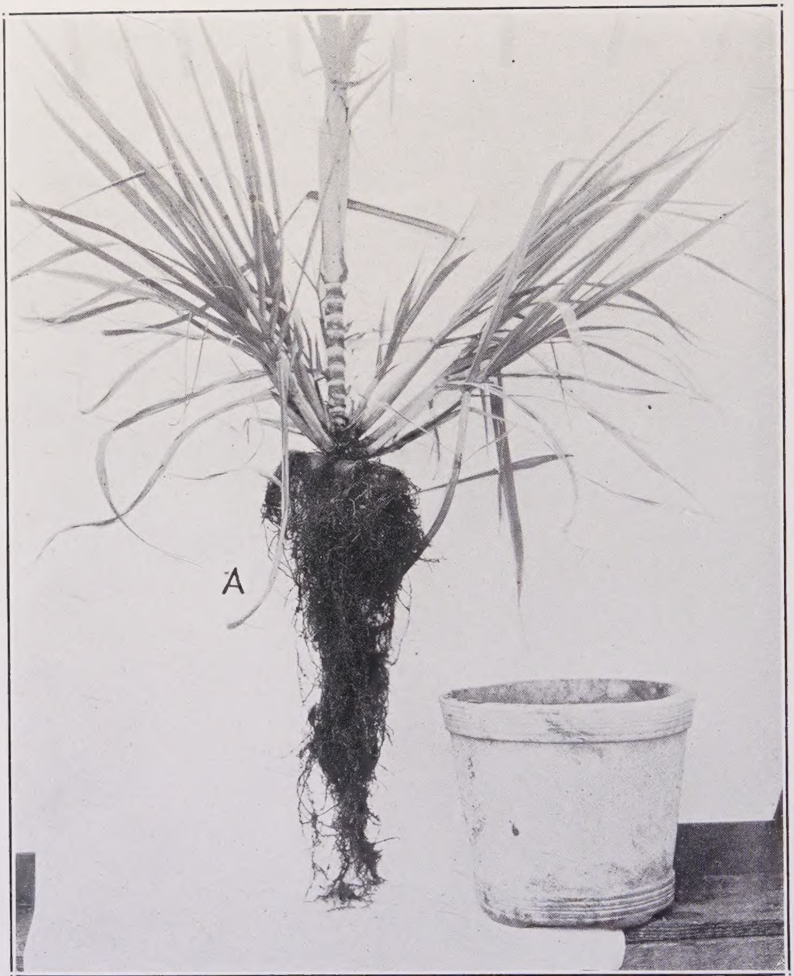


Fig. 3. This shows the complete root system when none of the roots have been trimmed.

proper time to do it? Most of us think the sooner the better. Reasoning from the above results, this may be wrong. The old roots of the stool are still functioning. As long as they do, the stump will remain healthy, as the living plant has the power to resist invading organisms. Now, if we come along and off-bar deeply and cut off the living old roots before new shoots have appeared and formed roots of their own, we stop all life and the old stump will immediately begin to rot. Of course, we never cut off all the roots in off-barring and this takes place only in part.

From the above, it would seem that the ideal time to off-bar is after the ratoons have begun to grow, but before their roots have attained such length as to be cut in off-barring. In this way, we keep the old stump alive until the new stalks are self-supporting.

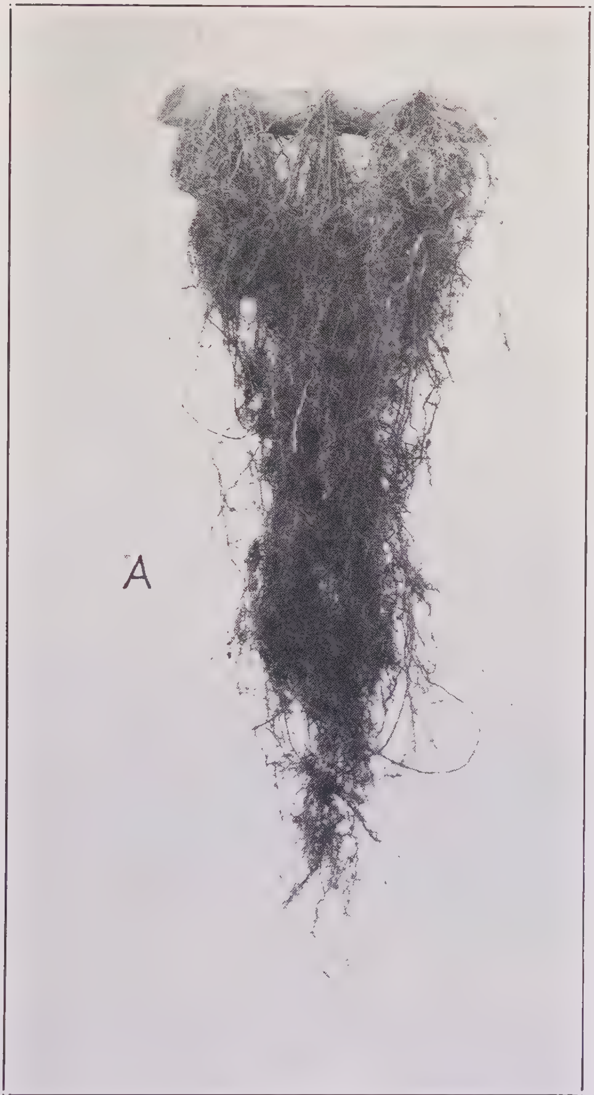


Fig. 4. The root system of the seed piece planted in pot A.

U. K. Das, who had active charge of the test, supplies the following details of the work:

Materials

Pots: Six concrete pots were selected. Three of them, marked A, B and C, had a capacity of about 0.9 cubic feet, the other three marked D, E and F, of about 0.6 cubic feet. All the pots were filled with a soil mixture consisting of field soil and mud press in equal proportions.

Seed Pieces: Three-joint, one-eye seed pieces were taken from young H 109 cane and planted on November 9, 1924.

Fig. 5. The root system of seed piece planted in pot B where the roots have been trimmed from the growing stalk.

Procedure

Planting: The cuttings were planted in the concrete pots on the morning of November 9, 1924, at a depth of about an inch. The pots were kept in an open place.

Irrigation: All the pots received uniform irrigation (the size of the pot being taken into consideration) during the whole period of the experiment.

Weeding: All the pots were weeded at regular intervals.

Trimming: As soon as the adventitious roots appeared, they were trimmed off with a pair of sharp scissors with the least possible injury to the plants. This was done every two or three days during the initial stages of the experiment and at longer intervals during the later stages.

Growth Measurements: After the plants had grown to a sufficient length, monthly growth measurements were taken till the end of the experiment.

Fig. 6. Pot C, which received the same treatment as pot B shown in Fig. 5.

Results

The young shoots began to appear on November 19, or ten days after planting. The growth thereafter was rather slow. The first adventitious roots were detected in some pots on December 28, 1924. From this time on, and for about three months, there was a brisk appearance of such roots in all the pots.

Controls

The idea of keeping control pots did not come until a little later. On January 18, two pots, one from among the three big sized pots, and one from among the three small sized ones, were marked "checks." Thereafter no roots were clipped off from the plants growing in these two pots.

There was no marked difference in growth and development of the plants. The following figures were obtained on the growth of the plants:

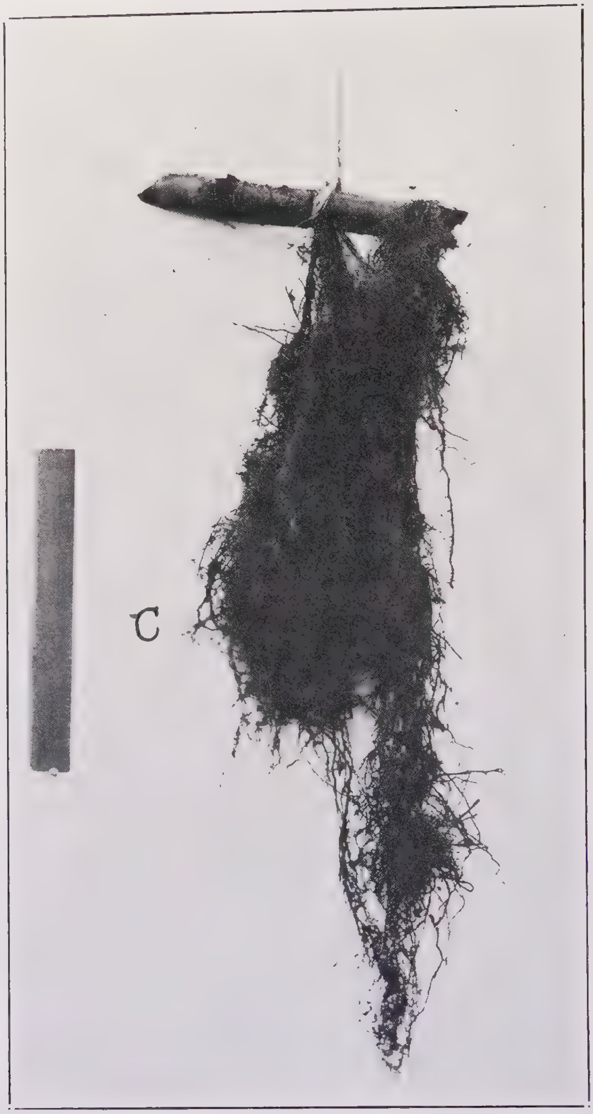


Fig. 7. The root system of seed piece planted in pot C where roots have been trimmed.

TABLE 1

Pot	1924 Dec. 10 To top of leaf	1925 Jan. 18 To topmost dewlap	1925 Mar. 16 To topmost dewlap	1925 Apr. 16 To topmost dewlap	1925 May 18 To topmost dewlap	1925 June 8 To topmost dewlap
A	1.83′	1.12′	1.81′	1.92′	2.13′	2.22′
B (check)	1.79′	.94′	1.65′	1.80′	2.00′	2.12′
C	1.75′	.96′	1.51′	1.62′	1.75′	1.80′
D	1.08′	.92′	1.34′	1.45′	1.63′	1.68′
E	1.66′	.93′	1.31′	1.37′	1.61′	1.66′
F (check)	1.08′	.91′	1.46′	1.57′	1.77′	1.91′

Fig. 8. Pot F, which received the same treatment as Figs. 5 and 6.

TABLE 2

Actual Growth of Plants

Pot	Jan. 10 to Mar. 16	Mar. 16 to Apr. 16	Apr. 16 to May 18	May 18 to June 8
A	.69′	.11′	.21′	.09′
B (check)..	.71′	.15′	.20′	.12′
C	.55′	.11′	.13′	.05′
D	.42′	.11′	.18′	.05′
E	.38′	.06′	.24′	.05′
F (check)..	.55′	.11′	.20′	.14′

During the latter stages of the experiment it was evident that all the plants were suffering from lack of nutrition.

It further appeared that the shoots arising from the mother plant in check pots were slightly bigger than the ones in the other pots, but the number of shoots were more numerous in the other pots. The following figures were obtained on June 8, 1925:

TABLE 3

Pot	Total No. of Shoots	No. of Shoots Bigger Than 0.5′
A	13	7
B (check)	8	6
C	12	7
D	8	6
E	7	6
F (check)	6	6

TABLE 4

Pot	Total Length of All Shoots Bigger Than 0.5′
A	5.24′
B (check)	7.07′
C	5.64′
D	4.00′
E	4.95′
F (check)	5.18′

For the purpose of comparison, the pots may be put into two classes, the bigger pots, A, B, C, in one class and D, E, F in another.

On June 16, the plants were removed from the pots and the soil washed away from the roots.

It was found that every plant had a thick and compact root system, but in the case of some plants, there was no root system corresponding to one or two nodes of the seed piece:

A—All joints of the seed piece have root system.
B—All joints of the seed piece have root system.
C—One joint has none, while another has few roots.
D—Two joints have no root system.
E—All joints have root system.
F—One joint has no root system.

This information may help us to explain some of the growth measurement figures.

It was also observed that the check Pots B and F had more numerous living, healthy roots than others. The living roots (those only which had the color of newly germinated roots) were counted.

Pot	Number of Healthy Roots	
A	80	
B (check)	128	
C	10	(These figures are by all means only approximate)
D	21	
E	8	
F (check)	68	

On cutting the seed pieces it was found that the tissue in seed pieces A and E was of normal color and taste.

The illustrations are by the Pathology department.

Comparison of Juices in Pith and Rind

By Wailuku Sugar Company

In the following experiment mature cane about twenty months old was used. Stalks were cut into lengths of about two feet and the rind sliced off as thin as possible with a cane knife. The piths and rinds were then run through the hand mill separately:

		Brix	Pol'n	Purity	Q. R.
W 2	Pith	20.16	18.95	94.0	6.7
	Rind	20.16	18.44	91.5	7.1
Lahaina	Pith	22.16	21.07	95.0	6.0
	Rind	22.56	21.04	93.3	6.1
	Composite	22.36	20.99	93.9	6.1

Hand mill juice samples taken of fields previous to harvesting checked fairly closely with the actual results obained at the mill, except in the case of W 2. The above experiment was run in order to determine whether or not the difference of purity between pith and rind had any bearing on the matter, because of the more complete crushing done in the factory as compared with that of the hand mill, which no doubt would give a larger proportion of rind juice in the factory sample.

We intend carrying out similar tests in the coming season to give us more definite data.

The Early Work of Albert Koebele in Hawaii

By R. C. L. Perkins

It was in 1890 that Koebele sent *Novius cardinalis* to Honolulu from California, where he had previously established it. Its success in controlling the cottony cushion scale, then one of the worst insect pests in the United States, had come to the notice of Mr. Jaeger, of Honolulu, who was interested in agriculture and horticulture, and it was through his sagacity that specimens were obtained from Koebele and introduced into Hawaii. As every one who pays any attention to such matters is aware, at this time, and previously, the above-mentioned pest was fully as destructive in the Islands as in California (where, of course, the interests were much greater) and some other "blights," as these insect pests were frequently termed, were almost equally destructive.

Thus we read that coffee, which had been introduced in 1825, by the middle of the century had become quite an industry on Kauai, but this was abandoned in 1856 owing to the ravages of "blight" said to have been introduced in 1850.

In 1876, the Rev. T. Blackburn, an expert entomologist in Honolulu, wrote that "the fruit trees were afflicted with an incurable blight."

The success of the *Novius*, which soon became manifest, led to Koebele's subsequent engagement partly by the Hawaiian Sugar Planters' Association and partly by the Government, as was urged by Mr. Jaeger.

Early in 1892, the writer became acquainted with Mr. Jaeger, who was naturally very enthusiastic, not only about what had already been achieved, but as to what further success Koebele might attain. He was very much surprised when informed that the latter's work as an entomologist was little, if at all, known except in the United States.

In 1894, many Coccinellidae were introduced by Koebele, chief among which were *Cryptolaemus montrouzieri* and *Coelophora inaequalis*. In the earlier literature the latter is unfortunately always referred to as "*Coccinella repanda*," the name used by Koebele, and it was not till many years afterwards that we received named specimens of the true *repanda* from Australia and became aware of this error.

Probably either of these two ladybirds was even more valuable to the Islands than the *Novius*, owing to the fact that they preyed on pests which seriously attacked a larger number of plants than did the cottony cushion scale.

In 1892, throughout the Kona district, where I was then stationed, *Pulvinaria* covered many of the trees, which were in a dying condition and many, in fact, were dead. After the *Cryptolaemus* was taken there, this scale to a large extent disappeared. There may be some who still remember the strange appearance of the trunks of many of the larger ornamental trees in Honolulu in June, 1896, when the *Cryptolaemus* larvae, having become full-grown, congregated together so as to form large white patches covering several square feet of the surface, which was entirely hidden by them. Owing to the white covering of the larvae many people mistook these for scale insects and were actually destroying them. Photographs were taken of some of these tree trunks and copies are probably still extant in the possession of the Territorial Board of Agriculture and Forestry.

In June, 1895, many of the native trees in the kipukas that are found in the forest at various parts within eight or ten miles of the crater of Kilauea were covered with a conspicuous black Aphid and others less noticeable. Many of the *Pelea* trees, especially, were in a dead or dying condition, but other forest trees were affected. At this time single specimens of *Coelophora* were rarely noticed, having evidently just arrived at the locality. In September, the ladybirds were in thousands and when the same places were revisited in August, 1896, we were unable to find even a single specimen of the large black Aphid.

Other ladybirds introduced at this early period were *Rhizobuis ventralis*, *Platyomus lividigaster* and *Orcus chalybeus*, all of which were more or less successful and useful. Others were fully established at large, but later became either scarce or totally extinct. The history of some of these is interesting. No species appeared more promising for a time than *Chilocorus circumdatus*. At first

the larvae became extraordinarily numerous, entirely clearing some trees of the harder scales, but gradually the beetle became rarer and rarer, till after 1900 I myself saw only a few single individuals. *Novius koebelei,* so far as we are aware, disappeared still earlier, and so far as we know *Synonyche grandis,* by far the largest of introduced ladybirds, was common for only a very short time on some of the ornamental bamboos in Honolulu. *Leis conformis,* from which much was expected, was almost entirely a failure. The pretty *Coccinella pupillata* was noticed from time to time, but not in great numbers.

During the earlier years of his work, Koebele's visits to Honolulu were short and few, his material being liberated by the Commissioner of Agriculture, Joseph Marsden. Whatever may have been the latter's knowledge of agriculture, of entomology he had none beyond that of a few Latin names, to repeat which gave him a good deal of pleasure. No doubt Koebele's chief success with ladybirds as compared with other insects was due to this fact, for when liberated, full instructions having been given as to the place where they were to be turned out, they could look after themselves. But many small parasites were also sent, and of almost none of these is there any record, except *Chalcis obscurata,* which became very abundant throughout the Islands. As Koebele informed me, his special request that all the dead material should be saved for subsequent identification, was not attended to in any instance.

Owing to my own occupation in the forests of the different Islands and to Koebele's infrequent visits to Honolulu, we did not happen to meet during the earliest years of his work, but on returning from a considerable stay in the Kauai forests in 1895, I found him in Honolulu. Among other matters, we discussed the possibility of his economic introductions proving antagonistic to my own work on the native fauna, especially as some of the rarer species of native Hemerobiids, which had been unusually numerous on the Aphis-infested *Pelea* trees at Kilauea, had disappeared after the introduced *Coelophora* had eaten up the Aphis. Reference was made to this point in a brief account of Koebele's work which I wrote in 1896 and which was published in the following year in *Nature.* Imperfect as this account was, it at least had the effect of calling the attention of most European countries to his work and its possibilities.

As it was necessary for me, after I had met him, to do further work in East Maui, I persuaded Koebele to accompany me and share my tent, since he was anxious to obtain some knowledge of the forest insects, concerning which there were complaints. After spending some weeks in the high, wet forest of the windward side, we left our tent, and carrying as few *impedimenta* as possible, we worked about the summit and through the crater to the lee side, sleeping in the open or in such natural shelters as were available. Being lightly clothed we were a good deal troubled by the sharp frosts at night, which appeared abnormally cold after the fine hot weather of the daytime. I have referred to this, the first of several hard trips we made together, as it gave me the first opportunity to see what a very accomplished field worker Koebele had become. He was particularly expert at collecting difficult beetles, and had no doubt learned many wrinkles from his friend E. A. Schwarz, of Washington, in earlier years.

In 1897, I joined Koebele in California and accompanied him to Arizona and Mexico, where he hoped to obtain some natural enemy for the mealybug of the alligator pear. This had now become an unsightly pest, having been introduced since the earlier years of my collecting. The complaints about Lantana were already numerous and some preliminary investigation was made of the plant in Mexico, but at this time no attempt was made to introduce any of the insects attacking it.

In 1898 and 1899, I was in England working at the *Fauna Hawaiiensis*, but on my return (early in 1900) to the Islands I was still more in contact with Koebele than previously, since we not only made many collecting trips in company, but I did much study work in his office.

In 1900, the presence of a number of insects entirely unknown to me in 1897 was obvious. Chief among these was the melon fly (*Dacus cucurbitae*) and the cane leafhopper. The latter was noted first as a leafhopper new to the Islands, at Waialua, where it occurred in some numbers around the electric lights in 1900. Its connection with sugar cane was not known at the time; in fact not until a year or two afterwards, when it was reported by August Ahrens as injuring the cane on Oahu Plantation. There is no doubt that as a pest it first showed up on that plantation and it was probably introduced, or at least became established there first, about the year 1897. Had this insect occurred in earlier years, it is unlikely (considering its attraction by light) that I should not have noticed it, and quite impossible that Koebele, who was perfectly well acquainted with the accounts of the Javanese *vastatrix*, and was frequently in the cane fields investigating the cane borer and other cane insects, should have overlooked it. In fact when he first saw the leafhopper in the Islands he took it to be the same as the pest recorded from Java.

Also in 1900, the fern weevil (*Syagrius*) was first noticed in fernhouses in Honolulu on maiden-hair ferns only, and the possibility of its spreading to the native tree ferns of the forest was not thought of.

The introduction of the melon fly must have taken place at about the same time. Up to the time when I left the Islands in 1897 melons were almost a drug on the market, and except possibly for the Chinese, could hardly have paid for raising. After my return, one of the first settlers in the agricultural colony at Wahiawa informed me that he considered the presence of the melon fly by no means a calamity, as he was able to raise melons by adopting certain precautions and obtain a good price for them, whereas formerly it would not pay to grow them. The species was first described in 1899 from specimens obtained by Mr. Compere in Honolulu. Koebele had, however, previously collected the species on one of his trips to the Orient, before it was known in the Islands, and had noted it as a pest on plants of the melon family. In 1900, I found Hawaiian melons and cucumbers were almost unprocurable. It does not appear that Koebele made any concentrated effort to obtain parasites for *Dacus*, possibly because Compere was specially investigating fruit flies at the time. In Mexico, when engaged on Lantana work, he noted a fine parasite on other fruit flies, but he would not take the risk of attempting to send over puparia of these flies, for fear that by some accident the flies themselves might be introduced. He was always cautious in his

introductions and many of the Australian ladybirds he was afraid to send in their larval state for fear of introducing their parasites.

In addition to the one species, *Chalcis obscurata*, above mentioned, Koebele sent over many other parasitic Hymenoptera from various countries, Australia, America and the Orient, at a time when he was the only economic entomologist connected with the Islands. Many of these were parasites of scale insects and *Aleyrodes*, but *Ichneumonidae* were sent from America and *Braconidae* from Oriental countries.

No record exists of the minute scale parasites which were frequently sent. For instance, it is quite uncertain whether some of the established parasites on scales were the results of his sendings or whether they came by other means, but it is hardly probable that of the large number of species sent none survived, even though they had no expert handling on arrival. As Koebele was well acquainted with the exact localities of the scale insects in various grounds and gardens in Honolulu and gave exact directions, as to where the parasites were to be liberated, a certain amount of success probably resulted. Although he never cared to make any attempt to introduce birds, various species of frogs, toads and bats were sent, but the latter at any rate failed to become established, though individuals were seen alive for a year after their introduction.

Of his later work on the Lantana plant, the sugar cane leafhopper and some other less important insect pests, fuller published records exist and can be consulted.

Koebele was *par excellence* a field worker in entomology and his knowledge of living insects was of a most extensive character, as at one time or another he paid special attention to all orders, but chiefly to Coleoptera and Lepidoptera, to some of the minute Hymenoptera and to scale insects. At one period he did much rearing of micro-Lepidoptera for Professor Riley. As may be judged from the nature of his field work, the Coccinellidae or ladybirds were his especial favorites, and he collected great numbers of species in the various countries he visited. He was not a great reader of entomological literature, but certain systematic works he used continually, e. g., Maskell's and Green's Coccidae, and especially Crotch's book on the Coccinellidae, which accompanied him on all his travels. Of the classification and specific character structures of these groups he had an extensive knowledge, though he published no notes of a systematic nature on others excepting some official reports and even these were to him an uncongenial task.

His success in the field was due to his acute perception of the habits of insects, and unsurpassed perseverance, and he was naturally a very quick worker, so that with insects that are rare and difficult to obtain he could collect a greater number in a given time than most of the best field workers we have known. Under any circumstances he was a most pleasant companion on a trip, for even when the hardest and most uncomfortable conditions were added to ill success he remained cheerful and good humored, hoping to the last to achieve something by which a failure might be converted into a triumph. He met with many adventures in his varied traveling, and in unhealthy countries contracted many fevers, which failed to lessen his enthusiasm for his work, but he rarely spoke of his adventures. In his younger days, when collecting in Florida, he was down with severe fever and

has told us how, at the time, numbers of a fine Sphingid moth, the caterpillars of which he had laboriously collected, were emerging in numbers in the room in which he lay, and how he spent the night alternately in killing the specimens, lest they should damage themselves, and in lying in a fainting condition on the floor. As would naturally be expected, he was the discoverer of great numbers of species of insects which were new to science, and many were named after him by their describers.

Biographical Sketch of the Work of Albert Koebele in Hawaii

By O. H. Swezey

Mr. Albert Koebele was the pioneer economic entomologist in the Hawaiian Islands. He was one of the first, if not the very first, entomologist to engage in the introduction of their natural enemies as a method of combating insect pests. His early work in this line was in California, where he introduced from Australia in 1888-89, the lady beetle *Novius cardinalis* Muls. as an enemy to the cottony cushion scale, *Icerya purchasi* Mask., a serious citrus pest. This was a remarkable success, and was considered to have saved the citrus industry from ruin.

At this time, Koebele was in the employ of the U. S. Department of Agriculture, an appointment which commenced in 1881-82. It was in 1885 that he was transferred to the Pacific Coast region, where he established his home at Alameda, California. During the several years that he was working in California he was chiefly engaged in the introduction of beneficial insects. Two trips were made to Australia for this purpose. This period of work ended on September 30, 1893, when he resigned from the U. S. Department of Agriculture to take up similar work in Hawaii, at first under a Commissioner of Agriculture of the provisional government, later as entomologist of the Board of Agriculture and Forestry, after the latter was organized, and about 1903 or 1904 was placed on the staff of the Experiment Station, H. S. P. A., as consulting entomologist, which position he held at the beginning of the Great War.

It has been impossible to obtain exact records of the work and travels of Mr. Koebele during his early work in Hawaii. However, during 1894-95, he made an extensive tour of Australia, Ceylon, China and Japan in search of beneficial insects desirable of introduction. Many lady beetles were introduced at this time. Among those which have become established and continue effective up to the present are *Cryptolaemus montrouzieri* Muls., *Rhizobius ventralis* Erich. from Australia preying on mealybugs; *Orcus chalybaeus* (Boisd.), *Serangium maculigerum* Blkb. from Australia, *Chilocorus circumdatus* Schon. from China, *Sticholotis punctatus* Crotch from China, all on diaspine scale insects; *Coelophora inaequalis* (Fab.), *Platyomus lividigaster* Muls., *Diomus notescens* (Blkb.) from Australia and *Coelophora pupillata* (Schon.) from Hongkong, all preying on

ALBERT KOEBELE
Enlargement from a snapshot taken in a Honolulu garden about 1900. (Courtesy of W. M. Giffard.)

plant lice. Among parasites that were introduced on this trip are *Chalcis obscurata* Walker and *Microbracon omiodivorum* (Terry), both from Japan and parasitic on leafroller caterpillars, the *Microbracon* being especially effective on the sugar cane leafroller.

In 1896-97 considerable time was spent in Mexico, Arizona and California, from which places large quantities of lady beetles were sent, also many kinds of cutworm enemies, but apparently these mostly failed to become established.

In 1899-1900, Koebele went on another trip to Australia, spending some time in Fiji on the way, and also going to Hongkong on the return voyage. Many shipments of beneficial insects were made on this trip, particularly from Australia.

During the greater part of 1902, Koebele was studying the insects affecting lantana in Mexico, and sending to Honolulu those which he found to be particularly attached to lantana and not likely to become injurious to any other plants. At that time, Dr. R. C. L. Perkins was employed by the Territory and assisted

Koebele in his work. The parasite material sent by Koebele was taken care of by Perkins and liberations made in favorable places for them to become established, at the same time destroying parasites, many of which affected most of the insects which it was desired to introduce. The enemies to lantana which were successfully introduced were as follows: Two butterflies, *Thecla echion* Linn. and *Thecla agra* Hew., whose larvae feed on lantana flowers; two moths, *Crocidosema lantanae* Busck. and *Platyptilia pusillidactyla* Walker, whose larvae destroy the lantana flower clusters; a leaf-miner, *Cremastobombycia lantanella* Busck. whose larvae feed inside the leaves; a leaf-bug, *Teleonemia lantanae* Dist., the young of which feed so numerously on the under side of the leaves as to destroy them and check the new growth of the plant sufficiently as to prevent flowering; a stem gall-fly, *Eutreta xanthochaeta* Ald., whose larvae live in enlargements of the freshly growing stems; a seed-fly, *Agromyza lantanae* Frogg., whose larvae feed in the fruits, often destroying the seeds, and usually causing the fruits to dry up, so that they are not eaten by birds with the resultant scattering of seeds. The combined results of the work of these eight introduced insects is to greatly reduce the enormous production of seeds that formerly occurred on lantana and which were so widely dispersed by the ripened fruits being eaten by birds.

During the summer of 1903, Koebele investigated leafhopper parasites in Ohio, where the writer had published a note on a dryinid parasite of a leafhopper occurring in grass lands of that region. He sent many hundreds of these parasites, and other leafhopper parasites that he discovered, to Hawaii to be tried on the sugar cane leafhopper which at that time was becoming very destructive on many of the sugar plantations. All of these Ohio parasites failed, and in the early summer of 1904, with Perkins, Koebele went to Australia in search of leafhopper enemies. Many were discovered in Queensland and attempts made at their introduction. The only successful introductions were four egg-parasites, the most important of which was *Paranagrus optabilis* Perkins, the second in importance being *Ootetrastichus beatus* Perkins, which was secured in Fiji, where Koebele stopped a short time on the return from this trip. The work of these egg-parasites resulted in greatly checking the leafhopper pest so that it was no longer a menace to the sugar industry. Another introduction at this time was *Aphanomerus pusillus* Perk., an egg-parasite on the torpedo-bug *Siphanta acuta* Walker, which was a pest on coffee, citrus and other garden and ornamental trees.

When he returned from Fiji, a short time was spent in Honolulu in the summer of 1905, which was the last time Koebele was in Honolulu. He went to California shortly afterward, and at different times in 1906-8 attention was given to the study of sugar cane insects and their parasites in Mexico and to the enemies of hornfly in Mexico and Arizona. A number of minor introductions were made. Those that succeeded were: *Eucoila impatiens* Say from Arizona in 1906, a parasite on dipterous larvae in cow dung; *Azya luteipes Muls.* from Mexico in 1908, a lady beetle feeding on Lecanium scales; *Hyperaspis jocosa* (Muls.), from Mexico in 1908, a lady beetle feeding on *Orthezia insignia* Douglas.

The latter part of 1908, Koebele went to Waldkirch, Germany, his boyhood home, where he was born in 1852. This was mainly as an opportunity for the recovery of his health which had been greatly impaired by so much time spent

ALBERT KOEBELE

Enlargement from a family group taken at his former home in Germany, earlier than the preceding photograph. (Courtesy of W. M. Giffard.)

in entomological exploration and research work in fever-infested regions of the tropics. While there during the summers of 1909-11, he studied the enemies of hornfly, and sent much material to Honolulu, but little, if any, success was obtained by this. In 1910, on account of continued failing health, he was relieved from active duty, though still retained as Consulting Entomologist by the H. S. P. A. He continued living in Germany and was there during the Great War, on account of which he was reduced to very meager circumstances and both he and his wife suffered great hardships. At the close of the war, as soon as it was learned of their circumstances, attempts were made by the Hawaiian Sugar Planters' Association to arrange for their return to their home in Alameda, California. By the time that all arrangements were completed, however, he had become too feeble for undertaking such a trip. He continued to fail and his death finally occurred December 28, 1924, in his 73rd year.

The services rendered by Mr. Koebele and the benefits derived by the agricultural and horticultural interests of Hawaii by his introduction of beneficial insects cannot be estimated in dollars and cents. He made the beginning in this line of work, and much of the time was working alone, yet seventeen species of ladybeetles were successfully introduced by him and have become valuable factors in keeping reduced such pests as scale insects, mealybugs, plant lice and leaf-mites. At least six other ladybeetles were introduced and became established, but after a few years disappeared. The eight lantana insects were introduced by him, and about the same number of miscellaneous parasites of Diptera, Lepidoptera, etc. Following Koebele in this line of work, the other entomologists have introduced a larger number of beneficial insects and some of them have produced more valuable results, but this should not in any way lessen the credit to be given to him who was the pioneer in Hawaii in this important phase of entomological work.

Papers and reports by Koebele or concerning his Hawaiian work were published as follows:

Report of a trip to Australia to investigate the natural enemies of the fluted scale. U. S. D. A., Ent. Bul. 21, 1890.*

Studies of parasitic and predaceous insects in New Zealand, Australia and adjacent Islands.* U. S. Dept. of Agriculture, pp. 1-39, 1893.

Professor Koebele and his work. Planters' Monthly, XV, p. 103, 1896.

Report on insect pests. Planters' Monthly, XV, pp. 590-598, 1896.

Report of the entomologist of the Hawaiian government. Planters' Monthly, XVI, pp. 65-85, 1897.

Report of Professor Albert Koebele, entomologist of the Hawaiian government. Planters' Monthly, XVII, pp. 208-219, 258-269, 1898.

Report of Professor Albert Koebele, entomologist. Report of the Com. of Agr. and Forestry for 1900, pp. 36-49, 1901. Also in Planters' Monthly, XX, pp. 299-309, 1901.

Report of Professor Koebele on destruction of forest trees, Hawaii. Rept. of the Com. Agr. and Forestry, Hawaii, for 1900, pp. 50-60, 1901.

Notes on insects affecting the Koa trees at Haiku forest on Maui. Rept. of the Com. Agr. and Forestry, Hawaii, for 1900, pp. 61-66, 1901.

Report of Professor Koebele on Lantana scale. Rept. of the Com. Agr. and Forestry, Hawaii, for 1901-02, pp. 54-65, 1903.

Report of Professor Albert Koebele. Third Report of the Board of Com. of Agr. and Forestry, Hawaii, for 1906, pp. 159-164, 1907.

Insect investigations in Mexico. Fourth Rept. Board of Com. of Agr. and Forestry, Hawaii, pp. 89-97, 1908.

Report on the enemies of *Lantana camara* in Mexico, and their introduction into the Hawaiian Islands. Ent. Bul. No. 16, Exp. Station, H. S. P. A., pp. 54-71, 1923.

* This paper is concerned with Koebele's work before coming to Hawaii, but the knowledge gained thus was of great assistance when he began here, and deals with the same species as many of his early introductions to Hawaii.

Records of Introduction of Beneficial Insects Into the Hawaiian Islands

By O. H. Swezey

Apparently the first beneficial insect purposely introduced into Hawaii was the ladybeetle (*Novius cardinalis* Muls.), which is an enemy of the cottony cushion scale (*Icerya purchasi* Mask.). This was introduced from Australia in 1890 (probably via California) by Mr. Albert Koebele, who was engaged at that time in introducing beneficial insects into California to attack their orchard pests.

Since that time, there have been many species of beneficial insects successfully introduced into Hawaii, from various parts of the world, and by several institutions here. Mr. Koebele was engaged for this work in 1893. Between that time and 1904 many valuable ladybeetles were introduced, also parasites of scale insects. In 1904 the Experiment Station of the Hawaiian Sugar Planters' Association began introducing parasites for the sugar cane leafhopper, and has continued the work of introducing beneficial insects for one insect pest or another ever since. The Territorial Board of Agriculture and Forestry has also been active in this line of work; the United States Experiment Station and the Honolulu office of the United States Bureau of Entomology have also had a share in this important work.

The records of these introductions are very scattered, and in some cases very obscure, possibly entirely lacking in many cases. Herewith an attempt is made to put together for convenient reference the records of all successful introductions, so far as they could be found. They are grouped according to the various purposes for which they were introduced. The date of introduction is given, so far as known, the country from which introduced, and the particular pest on which it preys.

At the time when these various insects were being introduced, many others were experimented with, perhaps ten times as many as are included in this list. Some of these, for one reason, and some for another, have failed to become established. Possibly there are others of them that did succeed in becoming established, but not in sufficient abundance for them to come to our notice. In any such cases, of course, very little benefit could be derived from them. The majority of those listed have been of great benefit, and in some cases their particular host pests are entirely under control.

Ladybeetles Preying on Scale Insects, Mealybugs, Etc.

1890. *Novius cardinalis* Muls. From Australia via California. On cottony cushion scale.

? [1] *Novius koebelei*. From Australia via California. On cottony cushion scale.

[1] Abundant in 1897, but later disappeared.

1894. *Cryptolaemus montrouzieri* Muls. From Australia via California. ? On mealybugs.

1894. [2] *Rhizobius ventralis* Erich. From Australia via California. On mealybugs.

? [1] *Cryptogonus orbiculus* (Gyll.). Japan. On mealybugs.

1895, 1906, 1914. *Nephus* sp. near *bipunctatus* Kugel. Japan, South China, Philippines. On mealybugs.

1894. *Orcus chalybaeus* (Boisd.). Australia. Diaspine scales.

1894. *Serangium maculigerum* Blkb. Australia. Diaspine scales.

? *Lindorus lophanthae* Blaisd. California. Diaspine scales.

1895. *Chilocorus circumdatus* Schon. South China. Diaspine scales.

1895. *Sticholotis punctatus* Crotch. China, Japan. Diaspine scales.

1895. [3] *Pentilia nigra* Weise. China, Japan. Diaspine scales.

1908. *Azya luteipes* Muls. Mexico. Lecaniinae.

1908. *Hyperaspis jocosa* (Muls.). Mexico. *Orthezia.*

1922. *Curinus coeruleus* Muls. Mexico. *Pseudococcus nipae.*

1922. *Hyperasps silvestrii* Weise. Mexico. *Pseudococcus nipae.*

1922. *Nephus* sp. Mexico. *Pseudococcus bromeliae.*

1922. *Diomus* sp. Mexico. Mealybugs.

1922. *Diomus* sp. (four-lined). Mexico. Mealybugs.

Coccid Parasites

1894. ? *Aspidiotiphagus citrinus* Craw. China, Japan. On diaspine scales.

1905. *Scutellista cyanea* Motsch. California. *Saissetia nigra.*

1908. [4] *Comperiella bifasciata* How. Japan. Diaspine scales.

1915. *Leptomastidea abnormis* (Gir.). Sicily via California. *Pseudococcus kraunhiae.*

1922. *Pseudaphycus utilis* Timb. Mexico. *Pseudococcus nipae.*

1922. *Coelaspidia osborni* Timb. Mexico. *Pseudococcus calceolariae.*

It is probable that many of the other parasites established in the Hawaiian Islands on introduced Coccids are some of those that were purposely introduced, but on account of their identity not being known at the time of introduction definite records are lacking.

Ladybeetles Preying on Plant Lice

1893. [5] *Coccinella californica* Mann. California. (Disappeared after 1896.)

1894. *Coelophora inaequalis* (Fab.). Australia, Ceylon, China.

1894. *Platyomus lividigaster* Muls. Australia.

1894. *Diomus notescens* (Blkb.). Australia.

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[1] Abundant in 1897, but later disappeared.

[2] The ladybeetle introduced under this name, and for a long time considered as such, has recently been shown by Mr. Timberlake to be a species of *Lindorus.*

[3] Recorded as introduced, but this name is used by Koebele incorrectly, and the species supposedly introduced, although established, is as yet undetermined.

[4] Doubtfully established.

[5] Again introduced in 1905, but failed.

1895. *Coelophora pupillata* (Schon.). Hongkong.
Before 1894. [6] *Callineda conformis* (Boisd.). Australia. (Disappeared after 1906.)
1895. *Synonyche grandis* Thun. China, Japan. (Disappeared after 1896.)
1895. *Verania discolor* Fab. Hongkong. (Disappeared after 1896.)
1895. *Coelophora biplagiata* Swartz. Hongkong. (Disappeared after 1896.)
Scymnus, several undetermined species introduced; details of introduction not known.

Other Enemies of Plant Lice

Syrphid flies and Chrysopid flies were reported established by Koebele in 1897. It is not known which species, nor where from, nor when introduced.

1904. *Chrysopa* sp. Australia.
1907. *Trioxys* sp. ? California. Parasite on orange Aphis.
1919. *Micromus vinaceus* Gerst. Queensland.
1923. *Lysiphlebus testaceipes* (Cress.). California.

Enemies of the Sugar Cane Leafhopper

1904. *Paranagrus optabilis* Perkins. Queensland. Egg-parasite.
1904. *Paranagrus perforator* Perkins. Queensland. Egg-parasite.
1904. *Anagrus frequens* Perkins. Queensland. Egg-parasite.
1905. *Ootetrastichus beatus* Perkins. Fiji. Egg-parasite.
1906. *Haplogonatopus vitiensis* Perkins. Fiji. Parasite on nymph.
1907. *Pseudogonatopus hospes* Perkins. China. Parasite on adult.
1916. *Ootetrastichus formosanus* Timb. Formosa. Egg-parasite.
1920. *Cyrtorhinus mundulus* (Bredd.). Queensland and Fiji. Predacious on eggs.

Bruchid Parasites

1910. *Uscana semifumipennis* Gir. Texas. Egg-parasite.
1910. *Heterospilus prosopidis* Vier. Texas. Parasite on larva.
1921. *Lariophagus texanus* Cwfd. Texas. Parasite on larva.
1921. *Urosigalphus bruchi* Cwfd. Texas. Parasite on larva.
1921. *Glyptocolastes bruchivorus* Cwfd. Texas. Parasite on larva.
1921. *Horismenus* sp. Texas. Parasite on larva.

Fruit-Fly Parasites

1913. *Opius humilis* Silv. South Africa. On larva of *Ceratitis capitata.*
1913. *Diachasma tryoni* Cam. Australia. On larva of *Ceratitis capitata.*
1914. *Diachasma fullawayi* Silv. Africa. On larva of *Ceratitis capitata.*
1914. *Tetrastichus giffardianus* Silv. West Africa. On larva of *Ceratitis capitata.*
1913. *Dirhinus giffardii* Silv. West Africa. On pupa of *Ceratitis capitata.*

[6] Again introduced in 1904, but failed.

1913. [7] *Galesus silvestrii* Kieffer. West Africa. On pupa of *Ceratitis capitata.*
1916. *Opius fletcheri* Silv. India. On larva of *Bactrocera cucurbitae.*

Other Enemies of Diptera

1906. *Eucoila impatiens* Say. Arizona. On larva of *Sarcophaga.*
1909. [7] *Bathymetis* sp. Germany. On puparium of horn-fly.
1909. *Hister bimaculatus* L. Germany. Predacious on maggots.
1913. *Muscidifurax raptor* Gir. & Sand. South Africa. Parasite on puparia.
1914. *Pachycrepoideus dubius* Ashm. Philippines. Parasite on puparia.
1914. *Spalangia philippinensis* Ful. Philippines. Parasite on puparia.
1914. *Spalangia* sp. Africa. Parasite on puparia.
1921. *Creophilus erythrocephalus* Fab. Australia. Predacious on maggots.

Parasites of Leafrollers and Armyworms

1895. *Microbracon omiodivorum* (Terry). Japan. On larva of leafrollers.
1895. *Chalcis obscurata* Walker. Japan. On pupa of leafrollers, etc.
? *Amblyteles koebelei* (Sw.). California. Armyworm parasite.
? *Amblyteles purpuripennis* (Cress.). California. Armyworm parasite.
? *Frontina archippivora* Will. North America. Armyworm parasite.
1923. *Euplectrus platyhypenae* How. Mexico. Armyworm parasite.
1924. *Archytas* sp. Mexico. Armyworm parasite.

Miscellaneous

1904. *Aphanomerus pusillus* Perk. Queensland. Egg-parasite of *Siphanta acuta.*
1909. *Blastophaga psenes* (Linn.). California. Caprifier of edible fig.
1910. *Ceromasia sphenophori* Vill. New Guinea. Parasite of larva of *Rhabdocnemis obscura.*
1916. *Paranagrus osborni* Ful. Philippines. Egg-parasite of corn leafhopper.
1916. *Scolia manilae* Ashm. Philippines. Parasite of larva of *Anomala* and *Adoretus.*
1917. *Dolichurus stantoni* Ashm. Philippines. Parasite on nymph of roach.
1921. *Ischiogonus syagrii* Ful. Australia. Parasite of larva of Australian fern weevil.
1921. *Pleistodontes froggatti* Mayr. Australia. Caprifier of *Ficus macrophylla.*
1922. *Pleistodontes imperialis* Saund. Australia. Caprifier of *Ficus rubiginosa.*
1922. *Notogonidea luzonensis* Rohwer. Philippines. Parasite of field cricket.
? *Stethorus vagans* Blackburn. Predacious on leaf-mites.
1922, 1925. *Bactra truculenta* Meyr. Philippines. Borer in nut grass.

Lantana Insects

1902. *Agromyza lantanae* Frogg. Mexico. Larvae in seeds.
1902. *Thecla echion* Linn. Mexico. Larvae on flowers.
1902. *Thecla agra* Hew. Mexico. Larvae on flowers.

[7] Doubtfully established.

1902. *Crocidosema lantana* Busck. Mexico. Larvae in flower clusters.
1902. *Platyptilia pusillidactyla* Walk. Mexico. Larvae in flower clusters.
1902. *Cremastobombycia lantanella* Busck. Mexico. Leafminer.
1902. *Teleonemia lantanae* Distant. Mexico. Leaf-bug.
1902. *Eutreta xanthochaeta* Aldrich. Mexico. Stem gall-fly.

INTRODUCED INSECTS WHICH FAILED TO BECOME ESTABLISHED

Among the large number of beneficial insects whose introduction has been attempted in Hawaii, by far the larger number have failed. It is impossible to give a complete list of all of these, as for many of them no records were kept, especially as in many cases their identity was not known, and since they failed to become established no attempt was made at determining them. In the lists as here given those are included that are not as yet known to have become established, although they may yet be found established later on. Sometimes an introduced insect has not been recovered for several years after its introduction. Then, too, some may be included which became established at first but have disappeared and have not been recovered in more recent years. Some are of too recent introduction for their establishment to be known as yet.

These lists are grouped according to their hosts, or the purpose for which they were desired.

Introduced Ladybeetles that Failed

Ladybeetles	Locality	Host
1891. * *Chilocorus bivulnerus* Muls.	California	*Lecanium*, etc.
1893, 1906. *Hyperaspis postica* Lec.	California	Mealybugs
1893. *Hyperaspis depressa* Casey	California	Mealybugs
1893. *Hyperaspidius comparatus* Casey	California	Mealybugs
1893. *Scymnus* sp.	California	Mealybugs
1894. † *Hyperaspis undulata* Say	California	Mealybugs
1895, 1906. *Rhodolia fumida* Muls.	China	*Icerya purchasi*
1895. *Rhodolia pumila* Weise	China	*Icerya purchasi*
1895. *Synonyche grandis* Thun.	China	Plant lice
1895. *Verania discolor* Fab.	Hongkong	Plant lice
1895, 1905. *Chilocorus similis* Rossi	Japan	Scale insects
1895. *Hyperaspis japonica* (Crotch)	Japan	Mealybugs
1896, 1905, 1910. *Hippodamia convergens* Guer.	California	Plant lice
1896. *Cycloneda sanguinea* Linn.	California	Plant lice
1896, 1902, 1906, 1908. *Chilocorus cacti* Linn.	California and Mexico	Scale insects
1896, 1902, 1906. *Hyperaspis lateralis* Muls.	California and Mexico	Mealybugs

* This species was again introduced in 1894. It was found breeding in 1896, but later disappeared.

† Several species of *Hyperaspis* and large quantities of other California ladybeetles were introduced in 1894. *H. undulata* was observed 10 months later. None of them found since.

1896.	*Psyllobora taedata* Lec.	California	*Oidium*
1899.	*Anisorcus affinis* Crotch	Fiji	Scale insects
1904.	*Neda testudinaria* Muls.	Australia	Plant lice and young leafhoppers
1904, 1906.	*Verania lineola* (Fab.)	Australia and Fiji	Plant lice and young leafhoppers
1904.	*Verania frenata* (Erich.)	Australia	Plant lice and young leafhoppers
1904.	*Orcus cyanocephalus* Muls.	Australia	Plant lice and young leafhoppers
1904.	*Orcus bilunulatus* (Boisd.)	Australia	Plant lice and young leafhoppers
1904.	*Orcus lafertei* Muls.	Australia	*Pseudococcus nipae?*
1904.	*Platyomus koebelei* Blkb.	Australia	Coccidae
1905.	*Hippodamia ambigua* Lec.	California	
1905.	*Coccinella californica* Mann.	California	
1906.	*Archaioneda tricolor* var. *fijiensis* Crotch	Fiji	Plant lice and young leafhoppers
1906.	Reddish yellow ladybeetle	China	
1906.	*Exochomus pilatei* Muls.	Arizona	Avocado mealybugs
1906.	*Exochomus marginipennis* Lec.	Arizona	Avocado mealybugs
1906.	*Hyperaspis limbatus* Casey	California	Mealybugs
1906.	*Thalassa montezumae* Muls.	Arizona	Lecaniid
1907.	*Hyperaspis 8-notata* Casey	Mexico	Avocado mealybug
1909.	*Adalia bipunctata* L.	Germany	Plant lice
1909.	*Coccinella septempunctata* L.	Germany	Plant lice
1911.	*Coccinella bipunctata* L.	Germany	Plant lice
1913.	*Coccinella bruckii* Muls.	Japan	Plant lice
1919.	*Coccinella arcuata* Fab.	Australia	Plant lice
1919.	*Coccinella repanda* Thunb.	Australia	Plant lice
1924.	Several ladybeetles	Canal Zone	Pineapple mealybug

Other Scale Enemies

1904.	Chalcid	Australia	Mealybugs
1904.	*Thalpochares* sp.	Australia	*Eriococcus*
1906.	Chalcid	Arizona	Mealybugs
1910.	Chalcids	Germany	Coccids
1924.	Chalcids	Canal Zone	Pineapple mealybug

Introduced Leafhopper Enemies that Failed to Become Established

1903.	Several dryinids	Ohio and California	Parasites on young
1903.	*Anagrus columbi* Perk.	Ohio	Egg parasite
1904.	*Epipyrops,* several species	Australia	Predacious
1904.	Earwigs	Australia	Predacious
1904.	Several dryinids	Australia	Parasites on young
1905.	Stylopid	Fiji	Parasite
1916.	*Ootetrastichus* sp.	Formosa	Egg parasite
1919.	*Drypta australis* Dej.	Queensland	Predacious
1919.	*Drypta,* 2 other species	Queensland	Predacious
1919.	*Paederus* sp.	Queensland	Predacious

Anomala and Adoretus Enemies that Failed

1896. *Sarcophaga* sp.	Mexico	Parasite on Scarabaeid beetle
1913, 1916. *Tiphia* sp.	Japan	Parasite on grub
1915-16. *Craspedonotus tibialis* Schaum	Japan	Predacious
1916. *Tiphia lucida* Ashm.	Philippines	Parasite on grub
1916. *Tiphia segregata* Crawf.	Philippines	Parasite on grub
1916. *Tiphia ashmeadi* Crawf.	Philippines	Parasite on grub
1916. *Prosena* sp.	Philippines	Parasite of grub
1916. *Dexia* sp.	Philippines	Parasite of grub

Enemies of Armyworms and Cutworms that Failed

1896, 1906. *Tetracha carolina* Linn.	Mexico, Arizona	Predator
1896. *Omus californicus* Esch.	California	Predacious beetle
1896. *Cychrus cristus* Harr.	California	Predacious beetle
1896. *Cychrus interruptus* Min.	California	Predacious beetle
1896. *Cychrus striatopunctatus* Chd.	California	Predacious beetle
1896. *Calosoma,* 5 species	Mexico	Predacious beetle
1896. *Pasimachus tolucanus* Chd.	Mexico	Predacious beetle
1902. *Microgaster* sp.	Mexico	Internal parasite
1902. Braconid ?	Mexico	External parasite
1902. *Euplectrus* sp.	Mexico	External parasite
1906. *Calosoma simplex* Lec.	Arizona	Predator
1906. *Calosoma,* other species	Arizona	Predator
1919. *Chlaenius* sp.	Australia	Predator
1924. *Apanteles militaris* (Walsh)	Mexico	Parasite

Enemies of Hornfly and Other Dipterous Maggots that Failed

1898. *Hister* sp.	Mexico	Predacious
1902. Dung beetles	Mexico	
1902, 1904. Dung beetles	Australia	
1905. Dung beetles	Australia	
1905. Braconid	Australia	Parasite
1906. *Eutrias* sp.	Arizona	
1906. Histerids	Arizona	
1906, 1922. *Pinotus colonicus* (Say)	Arizona and Mexico	
1906. Dung beetles, 6 species	Arizona	
1908. *Philonthus aeneus* Rossi	Germany	Predacious
1908. *Spalangia* sp.	Germany	Parasite
1908-12. *Figites* sp.	Germany	Parasite
1909. *Sphaeridium scarabaeoides* L.	Germany	Predacious
1909. *Aphodius fimetarius* (L.)	Germany	
1909-10. *Atractodes* sp.	Germany	Parasite
1909-10. *Alysia* sp.	Germany	Parasite
1910. Small Staphylinids	Germany	Predacious
1910. Small Hydrophilids	Germany	Predacious
1910. *Onthophagus nuchicornus* (L.)	Germany	
1911. *Polietes lardaria* Fab.	Germany	Predacious maggots
1914. Staphylinid beetles	N. Africa	Predacious
1919, 1922. *Onthophagus* sp.	Australia	
1921. *Onthophagus* sp.	Philippines	
1922. Several kinds of dung beetles	Mexico	

MISCELLANEOUS

1905.	Leafhopper	Australia	On dodder (*Cuscuta*)
1907.	Histerid	Java	Predacious on cane borer
1908.	Elaterid	Amboina	Predacious on cane borer
1908.	Histerid	Amboina	Predacious on cane borer
1910.	*Pimpla behrenzii* Cress.	California	Parasite on leafrollers
1910.	*Chalcis ovata* Say	California	Parasite on leafrollers
1910, 1919.	*Pteromalus puparum* (Linn.)	California	On cabbage butterfly
1913.	*Aphidius* sp.	Japan	Parasite on plant lice
1913.	*Lysiphlebus* sp.	Japan	Parasite on plant lice
1916.	*Apanteles* sp.	Formosa	Parasite on pink boll-worm
1919.	*Chelonus* sp.	Australia	Parasite on koa seed moth
1921, 1925.	Fig wasps for *Ficus retusa*	Hongkong	
1921, 1925.	*Larra luzonensis* Rohw.	Philippines	On mole cricket
1922.	*Larra* sp.	Philippines	On mole cricket
1922.	*Odynerus luzonensis* Rohw.	Philippines	On bean butterfly
1922.	Ichneumonid	Philippines	On bean butterfly
1922.	*Euplectrus* sp.	Philippines	On looping caterpillar
1922, 1925.	Curculionid	Philippines	Borer in nut grass
1923.	*Diaeretus* sp.	California	Parasite on Aphis
1923.	*Aphelinus* sp.	California	Parasite on Aphis
1923.	*Syrphus nitens* (Zetter)	California	Predacious on Aphis
1923.	*Syrphus opinator* O. S.	California	Predacious on Aphis
1923.	*Catabomba* sp.	California	Predacious on Aphis
1923.	*Eupeodes volucris* O. S.	California	Predacious on Aphis
1923.	*Scaeva pyrastri* (L.)	California	Predacious on Aphis
1923.	*Allograpta* sp.	California	Predacious on Aphis
1923.	*Myiophasia metallica* Towns.	Mexico	Parasite on cane borer
1923.	*Phanurus* sp.	Mexico	Egg-parasite of Zelus
1924.	*Podium haematogastrum* Spin.	Para, Brazil	Parasite of roach
1924.	*Larra*, 2 species	Para, Brazil	Parasite mole cricket

LANTANA INSECTS WHOSE INTRODUCTION FROM MEXICO WAS ATTEMPTED BUT FAILED TO ESTABLISH

1902. *Aerenicopsis championi* Bates. A Cerambycid beetle whose larva bores the stem.

1902. *Evander xanthomelas* Guer. A Cerambycid beetle whose larvae are borers in the base of stem and roots.

1902. *Apion* 2 sp. Curculionid beetles whose larvae feed in the seeds.

1902. Cecidomyiid fly whose larvae feed in flower galls.

1902. *Thecla pastor* Druce, and two other species of *Thecla* butterflies whose larvae feed on flowers.

1902. *Tephroclystis* sp. A Geometrid moth whose larvae feed on the flowers.

1902. *Hepialus* sp. A moth whose larva bores the stem.

1902. *Crocidosema* sp. A Tortricid moth whose larvae feed on flower heads and maturing seeds.

1902. *Octotoma scabripennis* Guer. A beetle whose larvae are leaf miners on lantana.

A Report on Mechanical Methods in Dusting Cane Fields

By H. Atherton Lee, J. P. Martin and Clyde C. Barnum

The use of fungicides in preventing fungus diseases of plants has been in use for almost a century. Such fungicides have chiefly been used in the form of liquid sprays and such liquid sprays in cane fields have never been feasible because of the large areas to be covered and the impassable condition of the crop after the cane is a few months old. On some crops liquid sprays have also been used to supply plant nutrients, as in the case of iron sulphate for pineapples and sodium nitrate, in one instance, on apples.

More recently, possibly within the last ten years, the use of fungicides in the form of dry dusts has been adopted for a number of garden and orchard crops. Several fungus diseases of plants have been very successfully held in check by such fungicidal dusts. With the increasing use of dust fungicides there has been a development of mechanical equipment for their application. This led to the

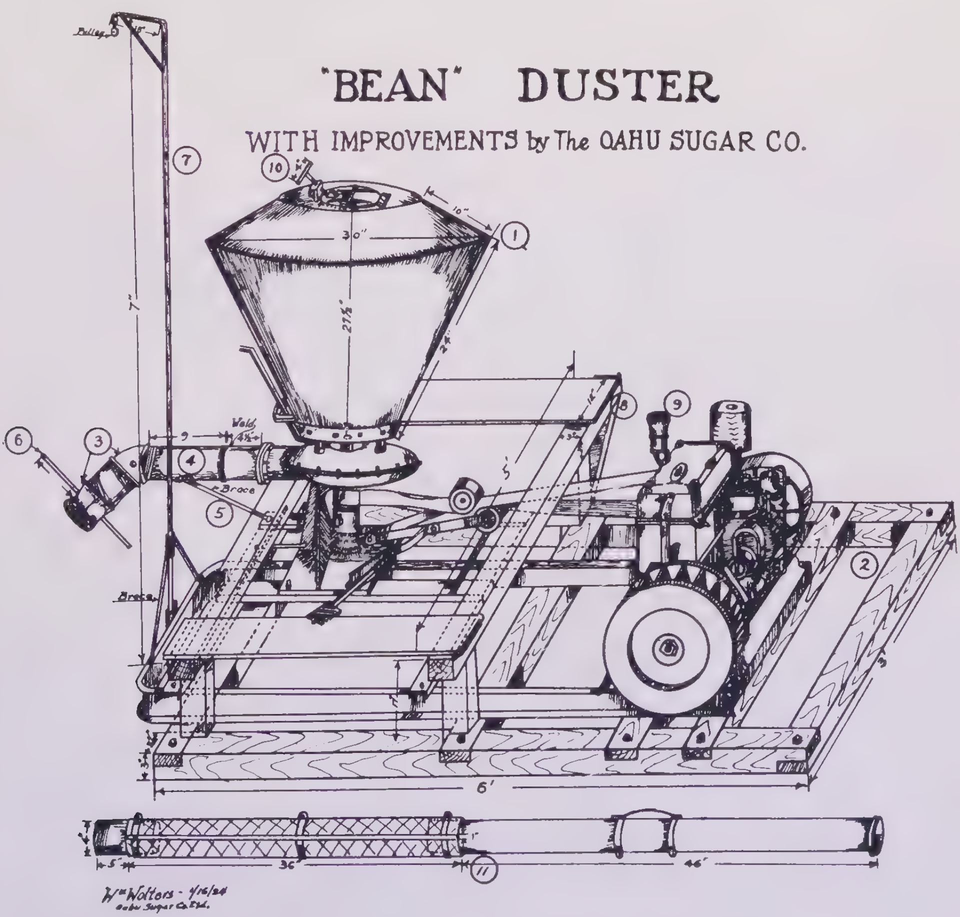


Fig. 1

Fig. 2. Showing the dusting machine and engine mounted on a motor truck.

belief that possibly the same mechanical equipment, with modifications, could be used in applying dust fungicides over the large areas of the cane fields of the character found in these Islands for preventing fungus diseases.

The Nature of the Dusting Equipment

A dusting machine, manufactured by the Bean Spray Pump Company, of San Jose, California, was secured. It consists of a hopper which holds the dust and contains an agitator to prevent the dust from clogging, a horizontally placed fan which is driven at 2,500 revolutions per minute, and an outlet tube of about four inches in diameter and six feet in length. The fan and agitator are belt-driven by a four-horse-power engine.

It was our idea that this equipment could be mounted on a light motor truck or cane car and the dust applied from the edges of the field. It seemed possible, also that in the event of inability to reach all parts of a field a narrow cart drawn by a mule could be specially constructed to be driven along the level ditches. To the present time, however, such a cart has not been necessary.

Important modifications in the equipment have been made by W. A. Wolters, of the Oahu Sugar Company, which have greatly simplified the work and increased the efficiency of the duster. A drawing showing the machine with Wolters' large-sized hopper, oak platform, outlet-tube support and modified outlet is shown in Fig. 1. A photograph of the equipment is shown in Fig. 2.

The studies in the prevention of eye spot were divided into two projects, the first to test the mechanical ability of this equipment to economically place the dust on the large cane fields, which are usual in these Islands, and the second to test out various fungicidal dusts for their toxic effect upon the fungus which causes eye spot. This report covers the progress in the first of these projects

only; that is, the tests to determine the mechanical ability of the dusting equipment to place the fungicide in a satisfactory manner on the cane over the large areas of our cane fields affected with eye spot disease.

Methods of Dust Application

It was first found that winds are not an aid in placing the dust on the cane but that the apparently still air in the early morning hours is essential for the dust applications. In the hours between 5:30 and 8:30 A. M. there is usually no perceptible wind, although on putting a few puffs of the dust in the air the movement of the dust usually shows very slow air currents. Such air currents, moreover, are usually fairly uniform for each field, and with one or two early morning trials, experience is gained which can be followed throughout the rest of the season's applications.

Dew upon the leaves in the early morning hours is also an essential feature. The dust spreads upon coming in contact with the moisture and as the dew dries the film of moisture and partially dissolved dust form a close adherence with the leaf. Applications of dust under such conditions are entirely resistant to winds and mild rains, although beating rains wash off the film to a considerable extent.

Probably the most satisfactory evidence of the distribution of the dust over the cane is shown by the photographs in Figs. 3, 4, 5, 6 and 7. By the use of discretion in placing the dusting machines in reference to the air currents, the application of the dust on the cane has been successful beyond our expectations. In some fields the early morning air currents do not allow the dust to be placed on certain small areas. It is often possible in such instances to take advantage of the first northeast winds, which arise a few hours after sunrise, to reach these spots with the power duster. However, when such a change does not work to advantage, laborers with hand dusting machines, or machines on mules, can be advantageously used in such small areas.

Good organization of the work is also indispensable. There are usually but three or at most four hours in the early morning when the best results can be obtained. For this reason in order to cover large areas mechanical difficulties should be foreseen and avoided, supplies should be on hand and a schedule of fields and plan of the work be in mind before the beginning of the work. There are a number of small points which the truck drivers and the machine operators learn only by experience and it was found that inexperienced labor often cause losses of considerable periods of time. For this reason the same crews are used for the work throughout the season. An experienced crew consisting of a truck driver and two machine operators with a skilled employee to observe the placing of the dust and direct the crew is ample for the operation of the equipment. In time it would possibly be practical to dispense with the skilled employee.

Costs of Dusting

An approximate average of thirty acres a day has been dusted during the past season and a possibility of eighty to one hundred acres a day may be achieved with the machines equipped with the Wolters' modifications. Depend-

Fig. 3. Showing the extent of the distribution of the dust; note the dust disseminating itself in the lower reaches of the field. This is in Field 59 of the Oahu Sugar Company.

Fig. 4. Showing the extent of the distribution of the dust in the Mokuleia section at Waialua.

ing on the efficiency of the crew, the cost of labor and equipment in dusting has in the past varied between 35 and 50 cents per acre, exclusive of the cost of the dust. This cost can be greatly reduced with greater experience and efficiency. In the trial applications an average of 20 pounds of dust to the acre has been used at each application; the dust in use has cost 1.15 cents a pound. It is possible that with experience the amount per acre can be reduced and in large quantities the cost per pound can be reduced. The maximum cost per acre, therefore, is 23 cents for the dust and 50 cents for the labor, or 75 cents total cost; with high efficiency the cost may be brought down to a much smaller figure. Even at the maximum cost, twenty applications per year could be made profitably in some of the severely affected eye spot areas, although with favorable weather conditions in many seasons, only ten applications or less may be necessary.

The dust used against eye spot during the past season (1924-1925) was admittedly a very weak fungicide. We have dusts available for next season's work which are more satisfactory, but we feel that it may be possible to obtain a still more effective dust with further research.

Fig. 5. Another view in the Mokuleia section at Waialua.

Fig. 6. A rear view of the apparatus and truck in operation at Waipahu.

Fig. 7. Showing the way the dust penetrates and infiltrates through the cane, reaching not only the topmost leaves but practically all parts of the plant.

Our conclusions from the first season's experiments are: (1) that mechanically there is no difficulty in placing dust fungicides on any of our cane fields, and (2) that our dust mixture for last season was entirely too mild as a fungicide for eye spot and that a more effective dust is necessary.

Other Uses for Dusts

It has seemed to us that there may be other advantageous uses for these dusting methods. Other diseases may be attacked by dust applications. In the event of the introduction of a new infectious disease, disinfectant dusts could be used to minimize the spread of the infection until total eradication could be effected. If the dusting methods continue on to a successful plantation practice, it would seem that an added security to the industry against cane diseases is available.

The use of dusts in applying nutrients also comes to mind. Ballard in California obtained a very beneficial effect on apple trees by spraying with sodium nitrate. Other possibilities suggest themselves. With the ability to economically place materials on the aerial parts of cane plants a new field is opened for methods in increasing yields and lessening losses.

It has seemed possible to us that airplanes could be advantageously used; the use of airplanes would, possibly, secure a better distribution of the dust. A slightly increased cost per acre could be allowed and still be advantageous to obtain the surety of the uniformity of distribution by airplanes.

This work with the dusting machines has only been possible with the cooperation of the other members of the Experiment Station staff. H. P. Agee, the Director, particularly has aided the work administratively and with valuable suggestions. E. W. Greene, manager of the Oahu Sugar Company, has placed the

use of his machine shop at our disposal and with George F. Renton, Jr., and J. B. Thomson, has encouraged and supported the work. A good start has been made in making the dusting of cane fields an established plantation practice, although to be conservative, unforeseen natural difficulties may still be expected until the work has been successfully carried on for several years.

Irrigation Investigations at Waimanalo

By Guy R. Stewart

The first report on the cooperative irrigation investigations at Waimanalo appeared in the *Record* of April, 1924. The present report deals with the continuation of these studies. The period covered here is slightly over a year, being from December 1, 1923, to December 30, 1924. The work was continued on a cooperative basis between the Chemistry department of this Station and Waimanalo Sugar Company. William Weinrich conducted the field work until October, 1924, when it was taken over by T. K. Beveridge.

Lines of Work Undertaken

The following lines of work have received attention during the past year:

- Irrigation Experiments,
- Water Supply Studies,
- Determination of Seepage Losses,
- Measurement of the Distribution of Water to the Fields.

Irrigation Experiments

We continued the experiments in Fields 8, 22 and 15, the preliminary results of which were given in our report last year, and started an additional experiment in Field 4.

Harvesting Results, Fields 8 and 22:

The experiments in Fields 8 and 22 were harvested in the 1924 crop and a summary of the yields obtained is given in Table I:

TABLE I

Amounts of Water Applied and Yields Obtained in Irrigation Experiments 1924 Crop

Treatment	Field 8 Irrigation applied during experiment	Field 8 Yield in tons sugar per acre	Field 22 Irrigation applied during experiment	Field 22 Yield in tons sugar per acre
Crop Cane..........	17.17 in.	10.27	19.38 in.	6.13
Extra Irrigation....	53.13 in.	11.71	56.11 in.	6.95

It will be remembered that these experiments in Fields 8 and 22 were started with cane which was in its second season's growth, about 12 months of age. The period in which extra irrigation was applied was from July 1st to November 15, 1923. After this time the rainfall was sufficient for the further growth of the crop. When our work was first undertaken at Waimanalo we were especially asked to find whether additional irrigation water would give as good cane growth as is obtained on the better irrigated plantations. In these fields we were only able to start additional irrigation after the crop was well advanced in age. We cannot state therefore what result will be obtained if full irrigation were available for a field throughout its entire growth until our experiments in Field 15 are harvested this year.

The indication obtained from this experiment is that the rate of growth obtained by full irrigation at Waimanalo is as good as that obtained in the Pearl Harbor district. The amount of increased crop, in extra sugar, which we obtained by applying this additional water to 12 months old cane was not sufficient to make it economically profitable. In one case, in Field 15, a gain of 1.5 tons sugar was obtained; and in the other, in Field 22, about 0.8 ton sugar. While these increases are appreciable, if water is short, such gains will not pay for the large amount of additional water required.

Irrigation Experiments in Fields 15 and 4:

The results of the first season's observations upon the experiments in Field 15 were given in our last season's report. They may be briefly summarized by stating that the application of 25.6 inches of irrigation water to the extra irrigated cane, contrasted with 4.1 inches of water to the crop cane, gave 2.5 times as much length of growth of stick, or eight times the volume of stick, obtained on the crop cane. At the time of our report the difference in growth fully corresponded to the difference in the amount of water supplied. Later in the winter, during the period of the highest humidity, eye spot was very prevalent in this portion of the field. The extra irrigated cane proved to be particularly susceptible to this fungus growth. There was considerable injury from this eye spot, so that it is not certain that the same differences which were found last year still persist. There is still a notably larger growth in the extra irrigated cane, but the possibility of eye spot injury to fully irrigated H 109 cane is a consideration which must be kept in mind at Waimanalo. This experiment will be harvested in the 1925 crop, so the final yield results will soon be available.

The experiment in Field 4 was installed because this is a notably open, light type of soil which is much less retentive of water than the soil in Field 15. The cane is D 1135 which was planted late in the fall of 1923. The experimental plots were laid out December 20, 1923. This area will also be harvested in the 1925 crop.

Amount of Water Applied:

The irrigation water applied to both these irrigation experiments is summarized in Table II:

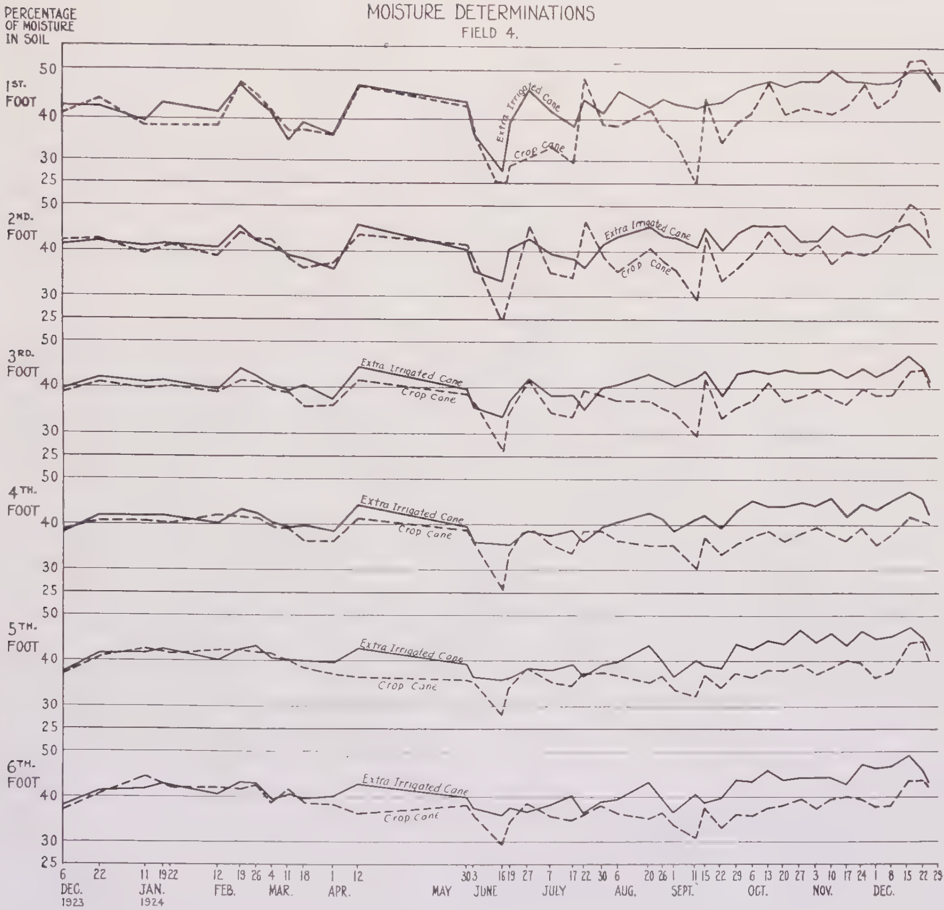
TABLE II

Summary of Irrigation

Field 4 Extra Irrigated Cane		Field 4 Crop Cane		Field 15 Extra Irrigated Cane		Field 15A Crop Cane		Field 15B Monthly Irrigation	
Date..........	Irrigation Acre Inches....	Date..........	Irrigation Acre Inches....	Date..........	Irrigation Acre Inches....	Date..........	Irrigation Acre Inches....	Date..........	Irrigation Acre Inches....
Jan. 17/24	1.66			Dec. 1/23	2.06			Feb. 2/24	3.28
June 18/24	1.27			Jan. 26/24	4.29	Feb. 9/24	3.98		
June 25/24	1.36	June 25/24	6.09	Mar. 15/24	4.38				
July 3/24	3.55			June 7/24	6.51			June 23/24	5.44
July 12/24	2.50			June 17/24	5.29	June 23/24	8.83		
July 18/24	3.55	July 18/24	5.00	July 5/24	4.12			Aug. 18/24	3.79
				July 14/24	4.32				
July 25/24	2.58			July 19/24	3.50				
				July 26/24	5.58				
Aug. 4/24	2.42			Aug. 9/24	2.92			Oct. 11/24	2.11
Aug. 9/24	2.51			Aug. 18/24	3.54				
				Aug. 23/24	3.51	Aug. 23/24	5.71		
Aug. 16/24	2.65	Aug. 16/24	1.58	Aug. 30/24	3.40			Nov. 1/24	2.32
				Sept. 6/24	2.15				
Aug. 22/24	2.40			Sept. 13/24	2.04				
				Sept. 20/24	1.24				
Aug. 29/24	4.91			Sept. 27/24	2.33			Dec. 6/24	3.80
Sept. 5/24	3.46			Oct. 4/24	1.93				
Sept. 12/24	3.69	Sept. 12/24	6.80	Oct. 11/24	3.19				
Sept. 19/24	2.30			Oct. 18/24	1.24				
Sept. 26/24	2.87			Oct. 25/24	1.87				
Oct. 3/24	2.40			Nov. 1/24	2.28				
Oct. 10/24	3.14	Oct. 10/24	2.54	Nov. 8/24	1.00				
Oct. 17/24	2.52			Nov. 15/24	2.24				
Oct. 24/24	2.05			Nov. 22/24	.89				
Oct. 31/24	1.55			Nov. 29/24	1.22				
Nov. 7/24	2.03			Dec. 6/24	1.48				
Nov. 21/24	2.32								
Nov. 28/24	1.94								
Dec. 5/24	1.66								
	63.29		22.01		78.52		18.52		20.74

It will be seen that the extra irrigated cane in Field 4 received almost three times as much water as the crop cane. The extra irrigated cane in Field 15 received a larger proportionate amount, the total irrigation was four times the crop cane, and three and eight-tenths as much as the monthly irrigated cane.

CHART I
MOISTURE DETERMINATIONS
FIELD 4.

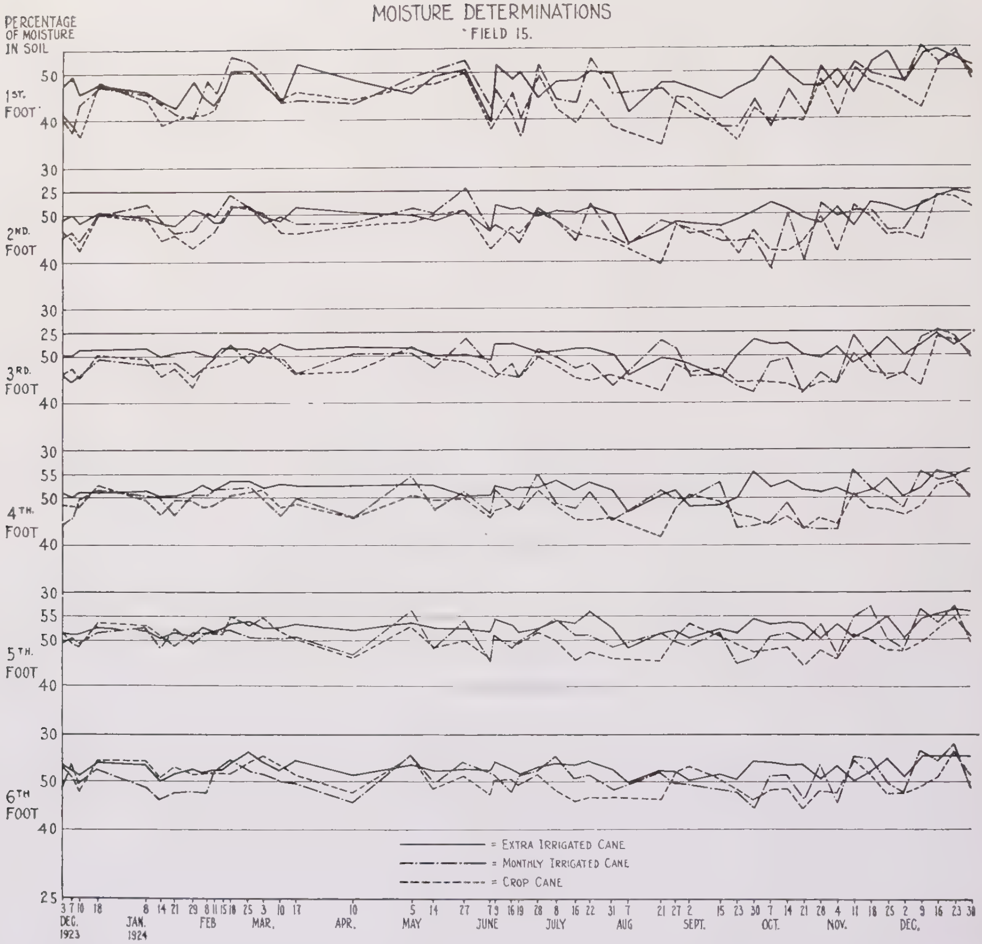


Determinations of Soil Moisture:

The moisture determinations made on the two fields are reported graphically in Charts I and II. Several interesting facts are shown by these graphs. In both fields the extra irrigated plots had a higher moisture content during the drier months of the year than the crop cane. There is, however, a striking difference in the moisture content maintained in the two soils by approximately the same amounts of water. The percentage of moisture in the less retentive soil occurring in Field 4 was notably lower both in extra irrigated and ordinary crop plots. In other words, it would probably take very much larger amounts of water to get as good moisture contents in the soil of Field 4 as in Field 15. This shows clearly the more effective use which is obtained from irrigation applied to a retentive soil than to a loose, open one.

The moisture contents in Field 4 rarely rose above 45 per cent in the extra irrigated soil until the cooler fall weather, and were still lower in the soil of the ordinary crop plots. This low range of moisture contents persisted, even down to the 5th and 6th foot in depth. In Field 15, the soil of the extra irrigated plots ranged from 45 to 50 per cent during most of the year, and was maintained at

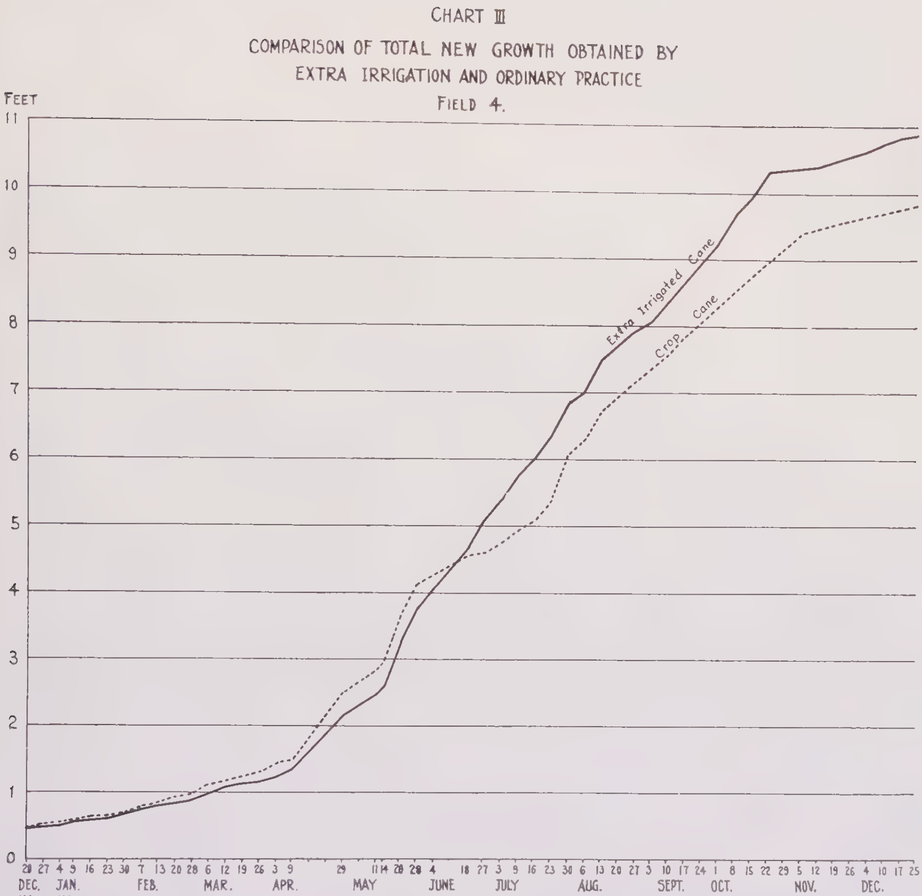
CHART II
MOISTURE DETERMINATIONS
FIELD 15.



this level quite steadily after irrigation started in June. The differences in moisture content between the soils of the extra irrigated and ordinary crop plots are only noticeable in the upper four feet. Below this point the moisture content is more uniform, though even there the extra irrigated soil generally maintained a higher moisture content.

Measurements of Growth:

The measurements of growth are shown graphically in Charts III, IV, V and VI which give the growth, both as total elongation and by the weekly rate. No attempt will be made to compare the growth made in the two fields, as the cane is not only of a different variety but also of a different age. In each field the extra irrigated cane showed a notably better growth than the ordinary crop cane. These results are summarized in Table III. The final comparison of the actual efficiency of growth will be obtained from the harvesting figures later in the year. It is interesting to note that a noticeably better growth was obtained in Field 15, with fairly regular monthly irrigations, than was made by the crop cane, which received practically the same amount of water in acre inches. This reinforces



our conclusion drawn from the first season's work, that moderate regular irrigations were likely to give the most efficient use of a limited water supply.

TABLE III

Summary of Growth Measurements—Elongation of Sticks of Cane

Field No.	Treatment	Avge. Length Dec., 1923	Avge. Length Dec. 30, 1924	Increase Feet	Gain Due to Irrigation
15	Extra Irrigation	6.5	18.8	12.3	3.3
15	1 Month Irrigation......	3.2	13.0	9.8	.8
15	Crop Cane..............	2.8	11.8	9.0	..
4	Extra Irrigation	.4	10.9	10.5	1.1
4	Crop Cane..............	.4	9.8	9.4	..

Growth of New Shoots:

The weekly count of the total shoots present in typical watercourses was carried on in all the experimental irrigation plots. This is of interest as it shows the type of growth developed by different amounts of water. It also indicates whether the shoots survive until the crop is finally harvested.

CHART IV

COMPARISON OF TOTAL NEW GROWTH OBTAINED BY EXTRA IRRIGATION, MONTHLY IRRIGATION AND PLANTATION PRACTICE

FIELD 15.

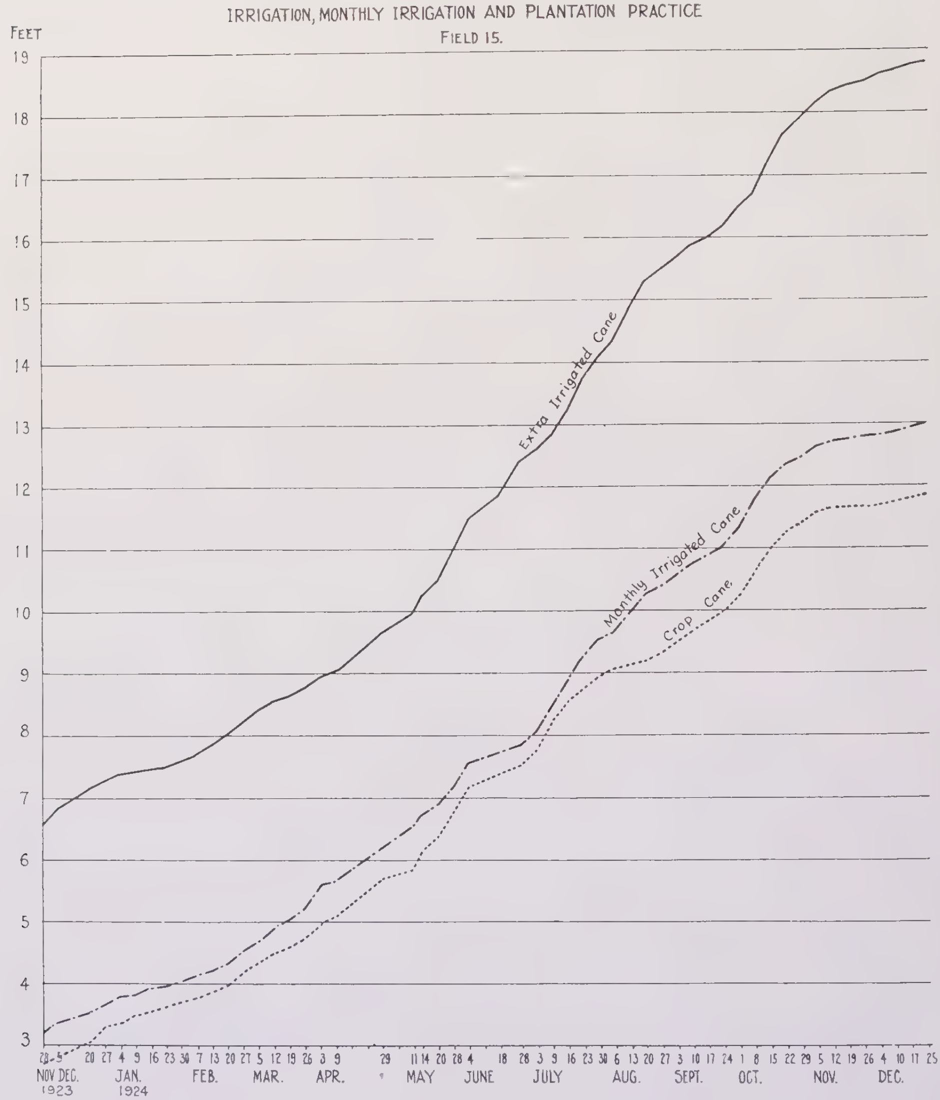


TABLE IV

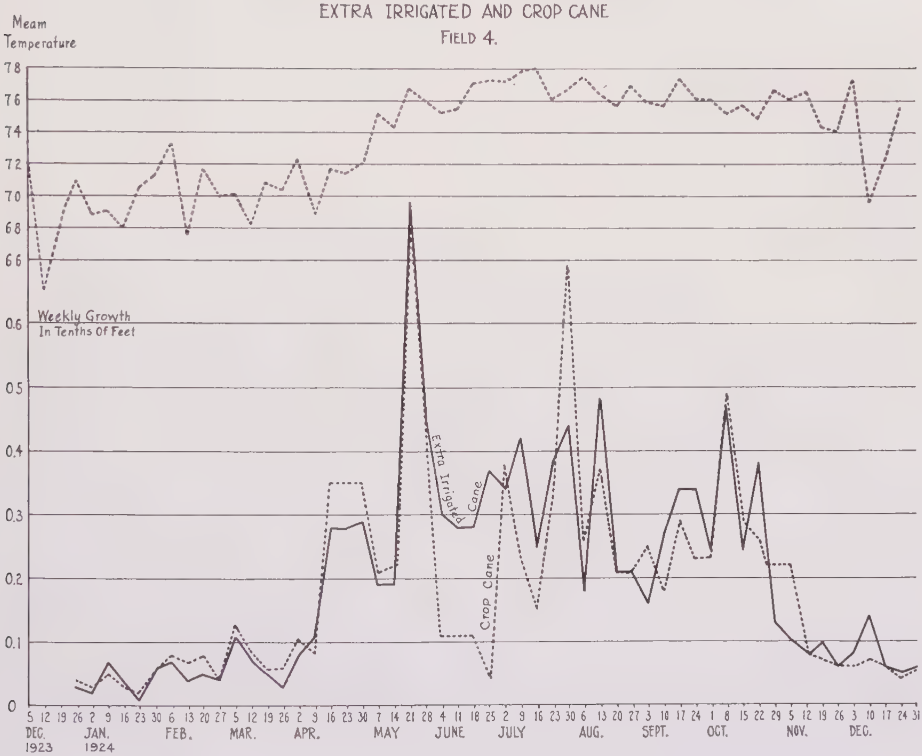
Development of Shoots in Irrigation Experiments

Field No.	Treatment	Number of shoots in watercourse December, 1923	Maximum Number present during season	Number of shoots surviving December 30, 1924
4	Extra Irrigated Cane...	77	206	154
4	Crop Cane.............	44	197	168
15	Extra Irrigated Cane...	83	102	71
15	Month Irrigated	98	120	88
15	Crop	101	120	84

CHART V

COMPARISON BETWEEN WEEKLY GROWTH OF EXTRA IRRIGATED AND CROP CANE

FIELD 4.



In Field 4, the watercourse chosen in the extra irrigated plot had a greater number of total small shoots than were present in the crop cane. With the more open growth prevailing in the crop cane, more new shoots were developed, but only a small part of these were of sufficient size to promise to become harvestable cane. The same relationship was found in Field 15. The crop cane and the 1 month irrigated cane had a greater number of small shoots and little sticks of cane than the extra irrigated cane. More adequate irrigation developed a smaller number of large sticks, of which a much greater number would be cane fit for the mill.

Effect of Temperature:

The effect of temperature upon cane growth is again clearly shown in Charts V and VI, where the mean temperature is plotted in comparison to the weekly rate of growth. In each of the two fields it is clearly seen that the decrease of the rate of growth in the fall is due to the drop in the mean temperature. The soil moisture had increased in the fall, due to lower transpiration and some rain, but this was not sufficient for rapid growth to continue when the temperature decreased.

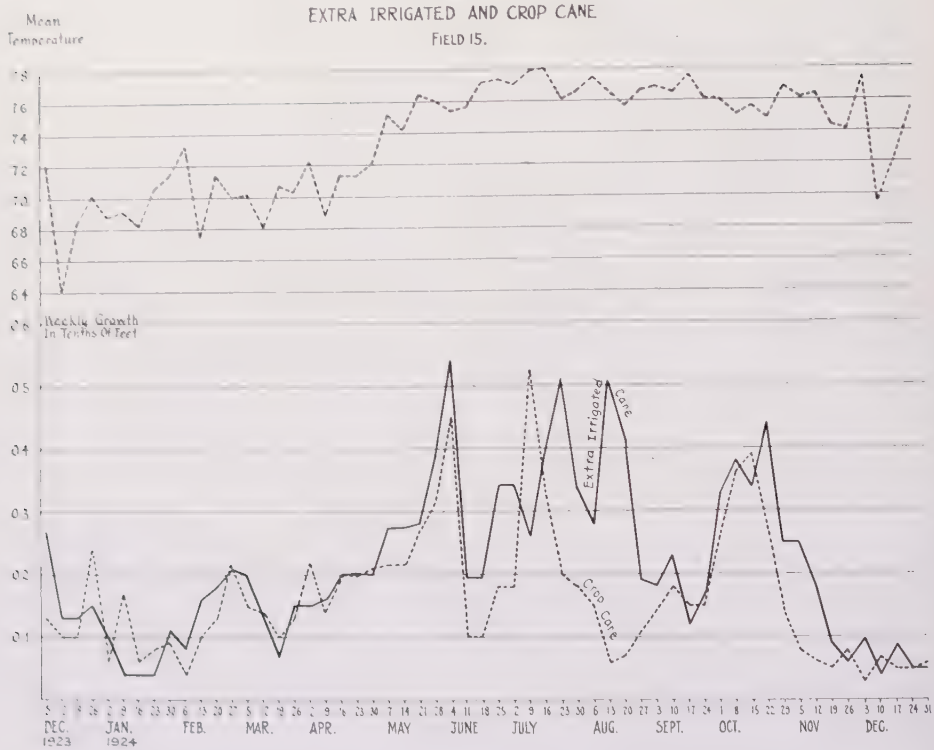
CHART VI

COMPARISON BETWEEN WEEKLY GROWTH

OF

EXTRA IRRIGATED AND CROP CANE

FIELD 15.



Fertilization:

The cane in Field 4 has received a first season fertilization of about 765 lbs. of mixed fertilizer per acre. This supplied 85 lbs. nitrogen, 45 lbs. phosphoric acid and 45 lbs. potash. The second season fertilization consisted of 550 lbs. nitrate of soda, which furnished 85 pounds nitrogen per acre. As the cane was D 1135 and the stand only moderately thick, it was not considered advisable to apply additional nitrogen to the extra irrigated plot. The gain obtained from this experiment will only be due to the use of extra water.

Our report last year noted that we had applied 100 lbs. additional nitrogen to the extra irrigated cane in Field 15. This appeared to be justified by the heavy growth and the fact that the cane variety was H 109. The additional nitrogen was applied in early August, before the regular fertilization, which was applied in October, furnishing 110 lbs. nitrogen. The second season fertilization was 75 lbs. nitrogen from nitrate of soda, which was applied to all the plots. The extra irrigated cane therefore received 285 lbs. nitrogen per acre, and the crop cane 185 lbs. This additional nitrogen must be taken into account when the increased sugar yield is balanced against the value of the additional irrigation water which has been used to produce the larger crop.

Water Supply Studies

In order to find what amounts of water were available for irrigation throughout the entire season, a series of additional weirs was installed by Mr. Weinrich. These covered the Maunawili ditch, Kailua ditch and Pump ditch. Monthly reports have been made of these sources of supply by Mr. Weinrich and Mr. Beveridge, but the results of these measurements may be summarized here briefly.

Maunawili Ditch:

The supply from this source was remarkably constant during the past season The daily average for the period of irrigation from June to November was as follows:

	Daily average	
June	2,715,409	gallons
July	2,590,783	"
August	[illegible]	"
September	[illegible]	"
October	2,363,304	"
November	2,851,062	"

These figures show that this source of water was extremely constant and reliable. The greater portion of this water came from the Maunawili Ranch, but about 400,000 gallons daily were derived from various small sources on the Waimanalo side of the ridge.

Measurements were also made of the principal sources of supply upon the Maunawili Ranch which are not being used by the plantation. These outside supplies ranged in flow from a maximum of a million and a quarter gallons to a minimum of one million gallons during the two driest months. These two low months were September and October. The average daily flow during this time was as follows:

UNUSED WATER MAUNAWILI RANCH

	September gallons daily	October gallons daily
Maunawili Stream	141,100	208,100
Omao Stream	225,700	238,300
Ainoni Spring	325,000	298,300
Makawao Stream	355,000	325,100
	1,046,800	1,069,800

These figures show that these additional sources of water are as constant in flow as the Maunawili water which is now being delivered to the plantation. The problem of utilizing this water is an engineering question which is outside the scope of this study. Our work has shown that the flow is sufficiently steady at the driest period of the year to warrant consideration of the cost involved in bringing this water into the plantation ditch.

Lagoon Pump:

The measurement of the water obtained this year since the second pump has been installed has shown a very steady flow. The water delivered has varied from a minimum of 2,600,000 gallons per day, to a maximum of 2,870,000 gallons. This water is of course not equal to the mountain water in purity, but it is a valuable source of supply and has been made entirely safe for use by mixing with the Maunawili water.

Kailua Swamp:

The water obtained from the Kailua swamp has been more variable in amount than either of the other two sources. The figures obtained from measurement of the water delivered showed that the swamp furnished 4 million gallons of water per day in June. As the demand for water increased upon the plantation the amount pumped was increased to an average maximum of 6 million gallons per day in August. This heavy drain upon the swamp steadily lowered the level of the water, so that only 2,227,000 gallons could be pumped in October. The decrease in level is clearly shown by the staff readings which were taken beginning June 3, 1924. Upon that date the water stood 3.4 feet above sea level. At the end of the heaviest pumping period, October 7, 1924, the staff reading was 3.9 feet below sea level. This showed a decrease in level of 7.3 feet, which would indicate that at least part of the function of the swamp is to serve as a reservoir for the accumulated run off from the higher hills.

Seepage Losses

In order to determine the possibility of obtaining greater economy in the distribution of water to the fields considerable attention has been devoted to the determination of the losses of water by seepage from the ditches. In considering the question of seepage, the problem naturally divided itself into a study of the condition of the ditches which bring the water to the plantation, and secondly a determination of the losses in the actual plantation ditches.

Two main supply ditches bring the water developed outside the plantation on the Maunawili Ranch, and in the Kailua swamp, to the plantation fields. The figures for the seepage losses on the Maunawili ditch from its start, up to and including the tunnel, where the water comes upon the plantation, have averaged about 5 per cent of the total supply. The distance is not accurately measured, but is between two and three miles. The seepage loss is therefore seen to be extremely low for an earth ditch, or about 2 per cent or less per mile.

The figures for the seepage loss on the Kailua ditch, before it reaches the plantation, showed a slight gain in water. The ditch is partly lined and some water enters the stream in one of the tunnels, but it is probable that this apparent gain was due to the manner in which the weir crest was originally set in one of the boxes. This setting is now being changed so that comparable figures will later be obtained. It is, however, fairly safe to state that the loss upon the Kailua ditch before it enters the plantation is probably negligible. Attention to seepage losses may therefore be centered upon the main plantation ditches.

TABLE V

Seepage Losses

Pump Ditch

Location of weir	Distance between weirs	Total flow gallons per 24 hours	Seepage loss gallons per 24 hours	Per cent of total flow lost	Per cent loss per mile
1—Field 22		1,285,000			
2—Field 11	3,320 ft.	1,020,000	265,000	20.64	32.82

Kailua Ditch

First Test

Location of weir	Distance between weirs	Total flow gallons per 24 hours	Seepage loss gallons per 24 hours	Per cent of total flow lost	Per cent loss per mile
Discharge pipe		4,442,800			
End of tunnels	11,648 ft.	4,664,600	none	....	....
Field 19	5,365 ft.	4,406,200	36,600	0.83	0.82
Field 15	3,276 ft.	3,996,600	446,200	10.04	14.84
Field 4	10,525 ft.	3,529,000	913,800	20.57	5.33
Field 3	4,915 ft.	3,015,900	1,410,900	31.76	12.02

Second Test

Location of weir	Distance between weirs	Total flow gallons per 24 hours	Seepage loss gallons per 24 hours	Per cent of total flow lost	Per cent loss per mile
Field 15		1,648,000			
Field 11	5,725 ft.	1,468,100	179,900	10.92	10.09
Field 4	4,700 ft.	1,399,700	68,400	15.05	4.64
Field 3	4,915 ft.	1,202,000	197,700	27.06	12.90

Maunawili Ditch

First Test

Location of weir	Distance between weirs	Total flow gallons per 24 hours	Seepage loss gallons per 24 hours	Per cent of total flow lost	Per cent loss per mile
Field 16		2,469,000			
Field 15	1,315 ft.	2,340,000	139,000	5.23	21.00
Field 14	7,275 ft.	2,113,000	356,000	14.42	6.67
Field 3	10,165 ft.	1,299,000	1,170,000	47.39	17.13
Field 1	5,623 ft.	1,125,000	1,344,000	54.43	6.38

Second Test

Location of weir	Distance between weirs	Total flow gallons per 24 hours	Seepage loss gallons per 24 hours	Per cent of total flow lost	Per cent loss per mile
Field 16		2,776,000			
Field 15	1,315 ft.	2,540,000	136,000	4.90	19.68
Field 14	7,275 ft.	2,372,000	404,000	14.55	7.00
Field 10	3,075 ft.	2,275,000	501,000	18.05	6.00
Field 4	4,200 ft.	1,661,000	1,115,000	40.17	27.82
Field 1	2,890 ft.	1,570,000	1,206,000	43.45	5.99

A study of the figures in the above table shows very clearly that there are appreciable losses in many parts of the plantation ditches. The highest loss per mile was found in the portion of the pump ditch which was measured. The seepage will be determined upon the remainder of this ditch as soon as the present crop is harvested. Several portions of the ditch are not accessible for the installation of weirs until the cane is cut.

Two portions of the Kailua ditch showed an appreciable loss, while two other sections only lost a moderate amount by seepage. This ditch appears to lose less water by seepage than the other two distributing systems. Even in this instance, however, the cumulative effect of the losses is quite appreciable. Almost

one-third of the water is lost when irrigation water reaches the end of the ditch in Field 3.

The Maunawili ditch showed a high loss in several portions. The cumulative effect of the seepage losses makes a very heavy water charge upon cane raised at the farther end of the plantation in Fields 1 and 3. Practically as much water is lost by seepage as finally reaches the cane.

In connection with the question of seepage losses, it is desired to allude again to the practice of growing cane along the main irrigating ditches and level ditches. This matter was touched upon in our report last year, where it was pointed out that cane growing in the ditches receives an unbalanced ration of too much water and too little nitrogen. The physical damage to the ditches is appreciable and the interference with normal stream flow and water distribution is very great. In addition to this, the penetration of the roots of cane or weed growth in the ditch banks greatly increases seepage loss.

There is a great deal of evidence as to the undesirable effect of growth in ditches. These observations have been made both under mainland conditions and in Hawaii. It is felt this matter deserves careful consideration in connection with the attempt to obtain greater economy in the use of water.

Distribution of Water to the Fields

The results obtained upon the determinations of soil moisture in Fields 4 and 15 exemplify the differences which may be found in two soils, where one is loose and open and the other is retentive of moisture. Similar soil variations are found in several portions of almost every plantation. It is therefore evident that if the attempt is made to keep the cane in each field in reasonably good condition to the eye this is likely to require the use of notably different amounts of water. In studying the problem of water economy it would therefore be desirable to know what amounts of water were applied to the different fields of the plantation. Should some soils prove to be notably loose and open in texture, requiring large amounts of water to produce satisfactory crops, or vice versa, producing poor crops with the same water which gave excellent yields elsewhere, it would be logical to concentrate to a greater extent upon the fields giving a better return per unit of water.

The desirability of such work was discussed with the manager, Mr. Chalmers, and it was found he was keenly interested in the value of the data which could be obtained. The plan has been developed of installing weir boxes, fitted for the Great Western Meters, in each of the fields when a new crop was started. In this way measurements were commenced upon a considerable part of the fields harvested in the last crop. It is planned to extend this work during the coming season and the attempt will be made to cover the entire plantation.

In this connection it would be desirable to follow the moisture content of a number of typical fields at intervals during the winter season. Very little winter irrigation has ordinarily been practiced at Waimanalo. Although the average winter temperatures are lower than those in summer, there is still sufficient mild weather at intervals to enable the cane to make a moderate growth

if the moisture is adequate. By following the moisture content of the fields it will also be possible to determine the time when it is necessary to start irrigation in the spring months.

Deductions to be Drawn from the Experimental Work:

The following conclusions appear to be justified by the work of the past two seasons: The results of the irrigation experiments point to the value of moderate, regular irrigations, which develop a continuous growth and enable the cane to utilize the rainfall to the best advantage. Extra irrigation applied to cane which was 10 to 12 months old, did not produce a satisfactory economic return. The effect of fairly full irrigation, from the time of planting, will be seen when the experiments in Field 15 are harvested this year. Up to the present our results show the greater value of regular monthly irrigation when contrasted with intermittent irrigation applied to the crop cane.

The value of these moderate, regular irrigations, and the difficulty of applying such small irrigations without excessive seepage loss, suggests the desirability of trying overhead irrigation upon an experimental scale. The harvesting results from this year's crop at Hawi Mill and Plantation Company, Ltd., are very encouraging. Better yields are being obtained by overhead irrigation than have ever been taken off their fields. It is believed the necessity for water economy at Waimanalo would warrant an experimental trial of possibly ten acres.

The differences in the moisture contents found in Fields 4 and 15 show the relative value of irrigation water applied to a loose, non-retentive soil, and to one which has a better water-holding capacity. The amounts of water applied to the two fields were not notably different, though the extra irrigated cane on the more retentive soil in Field 15 received slightly heavier irrigation. The moisture content was maintained at a more favorable level for crop growth in this better field. This demonstrates the advantage that may be obtained from using water on the best land.

The determinations of seepage losses have shown that attention may be confined, for the present, to the ditches inside the plantation. The seepage figures obtained on the Pump ditch and the Maunawili ditch showed a high rate of loss for portions of these ditches. The Kailua ditch showed an appreciable loss in two portions and a low loss in two others.

The high seepage loss on portions of the plantation ditches emphasizes the importance of keeping the ditches free from all growth. The roots of both cane and weeds increase the percolation of water out through the ditch banks. This unfertilized cane in irrigation ditches makes an extravagant use of water. At Waipio the fully irrigated, unfertilized plots have produced approximately 35 tons cane per acre. Similar adjoining plots receiving full fertilization have produced from 100 to 110 tons of cane per acre.

Recommendations for Further Work

1. Continuation of studies of seepage losses, after clearing the ditches of all growth.

2. Elimination of cane from all level ditches and distributing ditches.

3. The experimental trial of overhead irrigation.

4. Extend the measurement of irrigation water to all harvested fields, so as to determine the relative efficiency in sugar production obtained per unit of water applied.

5. Follow the moisture content of typical fields during the winter season, so as to determine if more winter irrigation would be advisable.

6. Install a series of growth, soil moisture and irrigation studies in typically different fields, as a further check on the efficiency of irrigation during the coming season.

An Illustration of Aluminum Injury to Sugar Cane

By W. T. McGeorge

For some time the Chemistry department has been studying the effect of aluminum salts on the poor fertility or so-called root rot on the acid plantation soils. Extensive investigations throughout the United States and Europe have shown the salts of this element to be the principal toxic constituents of such types, and we have found these salts almost universally present in acid Island soils of certain acidity. In the accompanying illustration there is shown the most clear-cut example of aluminum injury to sugar cane yet observed during our investigation. Both cane stalks are D 1135 from Honokaa Sugar Company. That on the left is from Field 11, in which "root rot" injury is very serious. The reaction of the soil in which this stalk was grown is pH 5.5, which is within the range (5.8 or less) at which Hawaiian soils contain aluminum salts in the soil solution. Chemical tests on this stalk showed the presence of large quantities of aluminum and iron at the nodal joints. The effect of the aluminum is well shown in the numerous adventitious roots and in the disintegration and discoloration of the tissues at the nodal joints.

The stalk on the right, while equally stunted in growth, gave only an extremely faint test for iron and aluminum at the nodes, was free from adventitious roots and disintegration or discoloration of the tissues. The reaction of the soil in which this stalk was grown is pH 5.82 or slightly outside the range at which the aluminum salts are soluble. This field has responded notably to nitrate, indicating that the stunted growth is due to a nitrate deficiency and that it is not associated with any toxicity of aluminum, thus confirming the chemical tests and illustrating their value in identifying aluminum injury.

Aluminum injury is confined almost entirely to mauka fields. The acidity of Island plantation soils as a rule increases with altitude. A notable exception is the Kau district of Hawaii, where cane is grown at an altitude of 2,500-3,000 feet and where there are no acid soils even at this altitude. In view of the excellent crops grown at the higher altitudes in Kau and the absence of "sour" soils in

Comparing D 1135, stunted by aluminum (left, Field 11), and nitrate deficiency (right, Field 19). Note adventitious roots and discolored nodes in the former. These are entirely lacking in the stalk on the right.

this district, the question arises: Is environment (altitude) the primary factor in the poor growth of cane on the mauka lands of Kauai and the Hamakua Coast district on Hawaii? or is it not rather the higher acidity of the soils in the latter districts with the toxicity of the aluminum salts which are present at these reactions? It is at least of more than passing significance that the principal difference between the mauka areas of Kau and other Island districts is the difference in soil reaction.

The Relation of Root Injuries to Root Failure in Lahaina Cane

By Guy R. Stewart

The study of the chemical factors in the soil which are associated with the failure of the root system of the Lahaina variety of cane has been the major research endeavor of the Chemistry department of this Station for the past two years. Evidence has accumulated in the course of this work which tends to show that several unfavorable soil conditions have interfered with the growth of Lahaina cane in the Island sugar lands. Among these harmful influences we may mention the effect of high soil acidity and the accompanying toxic quantities of soluble aluminum found in some mauka lands. Notable deficiencies of potash and phosphates also appear to be predisposing causes of root failure. Shortages of these plant foods are often found in the highly acid soils. In other instances accumulations of salts from the irrigation water have caused injury from the soluble salts left in the soil, and in some cases have reacted with the soil minerals to produce an unduly alkaline soil reaction.

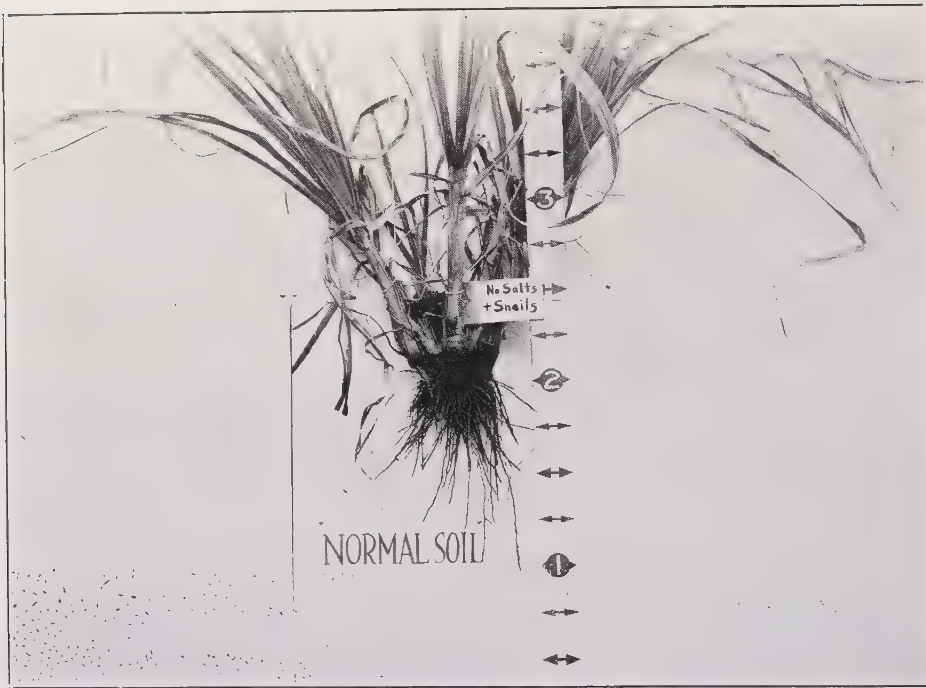
As these studies progressed it was frequently noted that a number of types of root injury often occurred in the cane fields. In some cases these root injuries consisted of definite cavities, possibly as large as a pin head; in other instances the holes were much smaller and were surrounded by reddish discolorations. Swezey (5) and others at this Station have reported that the larger cavities are often caused by minute snails. Pemberton (3) has shown that centipedes can cause similar damage to cane roots in the Honokaa district. Widespread root failure of sugar cane in Louisiana has been ascribed to snail injuries by Rands (4). The smaller minute root punctures with surrounding red areas, have been shown by Cobb (2) and Lyon to be caused by free living nematodes of the eelworm type.

In view of the frequency with which these root injuries occur, it appeared desirable to have some more definite information as to the relative effect of root injuries contrasted with toxic soil conditions. The following preliminary experiment was therefore planned and carried out as a cooperative endeavor by the departments of Chemistry and Entomology.

We desired to try the effect of two unfavorable chemical factors in the soil. One of these was high acidity with toxic amounts of aluminum in solution. The soil chosen was from a highly acid area in the Kaneohe district where Lahaina cane failed in the days when this land was in sugar cane. This soil showed a reaction of 4.8 on the pH scale. In order to have controls with a favorable reaction, part of the tubs with this soil were treated with lime at the rate of 6

Growth of Lahaina cane in a good soil, partially sterilized, with a high concentration of soluble salts.

Growth of Lahaina in the same soil, without salts.



Root destruction of Lahaina cane in a normal soil, without salts, in the presence of snails and free living nematodes.

tons per acre foot of soil and superphosphate at the rate of 15 tons per acre foot added. Preliminary tests showed these treatments were sufficient to counteract the effect of the soil acidity.

The other unfavorable condition to be tried was a high concentration of soluble salts similar to that left by the evaporation of a slightly salty irrigation water. Owing to the difficulty of reclaiming a soil with a high salt content, it was decided to take a good soil in which Lahaina grows well and add salts to part of the tubs in sufficient amount to equal the salt found in bad spots in some poorly drained fields. The soil chosen was from Field 12, Oahu Sugar Company, where Lahaina cane still grows well.

We desired to try the effect of the root attacks of snails, free living nematodes and centipedes, both in the presence and absence of the unfavorable acidity and high salt concentration. The following treatments were made in duplicate to large concrete tubs, each of which held approximately 500 lbs. of soil. Each tub was 2 feet square and 2 feet deep:

PLAN OF EXPERIMENT

Acid Soil from Kaneohe

Acid Soil Untreated	Acid Soil Untreated
Acidity Neutralized	Acidity Neutralized
Acid Soil Untreated to Receive Snails	Acid Soil Untreated to Receive Snails
Acidity Neutralized to Receive Snails	Acidity Neutralized to Receive Snails
Acid Soil Untreated to Receive Centipedes	Acid Soil Untreated Centipedes Added
Acidity Neutralized to Receive Centipedes	Acidity Neutralized to Receive Centipedes
Acid Soil Untreated Nematodes Added	Acid Soil Untreated Nematodes Added
Acidity Neutralized Nematodes Added	Acidity Neutralized Nematodes Added

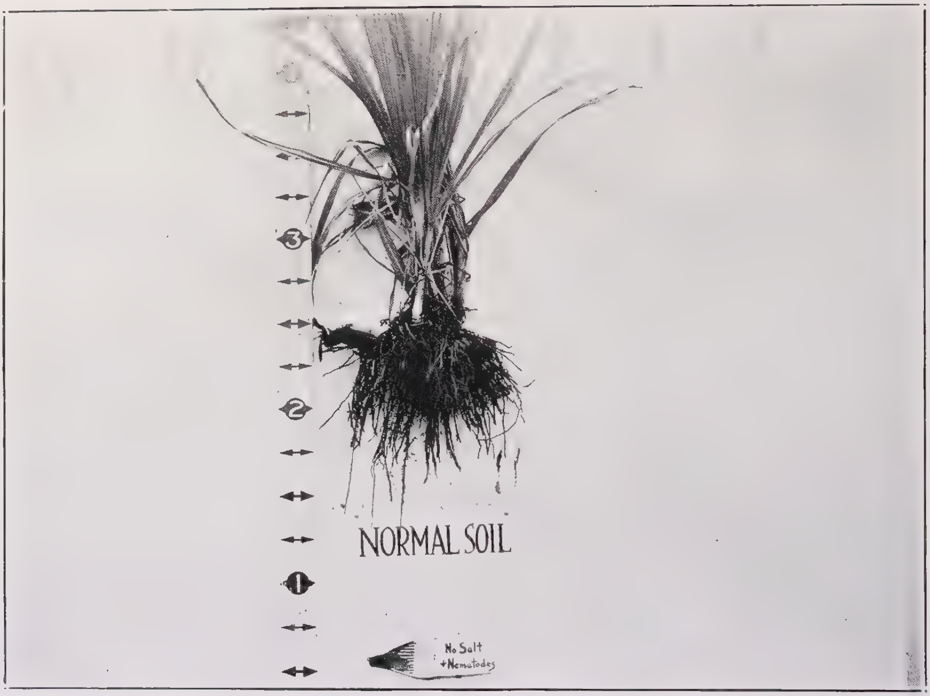
Normal Soil from Oahu Sugar Co.

Normal Soil Untreated	Normal Soil Untreated
Salts Added	Salts Added
Normal Soil to Receive Snails	Normal Soil Snails Added
Salts Added to Receive Snails	Salts Added to Receive Snails
Normal Soil to Receive Centipedes	Normal Soil Centipedes Added
Salts Added to Receive Centipedes	Salts Added and Centipedes Added
Normal Soil Nematodes Added	Normal Soil Nematodes Added
Salts Added and Nematodes Added	Salts Added Nematodes Added

This plan shows the arrangement of the duplicate tubs. It will be seen that half of the tubs of the acid soil were treated with lime and superphosphate, and half of the tubs of normal soil received salt treatments.

Before placing the soil in the tubs, it was subjected to partial sterilization by transferring it to small sacks holding about 10 lbs. These were then heated in a large autoclave at 15 lbs. pressure for one hour's time. We found by experiment that this period was sufficient to kill all soil inhabitants except the spores of fungi and bacteria. We desired to have the fungi and bacteria present in the soil in order to have them play whatever part they may in root deterioration.

Our original scheme, as indicated in the above plan, was to add snails, centipedes and nematodes to separate pairs of duplicate tubs in each series of treatments. We should thus have an opportunity in one series to observe the effect of these organisms upon the roots of Lahaina cane, both in a highly acid soil and in the same soil when the acidity was corrected. In the other series we should have the same organisms added to a thoroughly good soil, and to the same soil with a harmful amount of salt present.



There was greater root injury from nematodes in the normal soil, without salts, than where salts were added.

The tubs were all planted in November, 1924. We planned to add snails and centipedes to the respective pots as soon as the cane was well started. Mr. Swezey and Mr. Hansson spent many days searching for snails in the cane fields of Oahu. As a result of their efforts, we feel justified in stating that snails are not, ordinarily, sufficiently numerous in any large area of cane land on Oahu to exercise a harmful effect on the cane roots. Two minute snails, *Geostilbia Caecilioides baldwini* and *Subulina octona,* which are most concerned in root injury, have been noted in cane fields by various members of the Station staff. The only areas in which the molluscs have appeared to be numerous, have been poorly drained sections of land where the soil has been practically saturated with water. Under such conditions it is probable that they may increase for a time and become a factor in root injury.

Swezey and Hansson finally obtained a sufficient number of snails, 96, to add to one tub of cane. It was also difficult to find a sufficient number of small centipedes of the variety present in cane stools. Three tubs were eventually inoculated with centipedes.

The nematodes added to the tubs were of the minute eelworm type, which make a tiny red puncture where they enter the root. Cobb has identified this as *Tylenchus similis* (Cobb). These are not the variety which causes the large root galls commonly associated with nematode injury. The latter type is known as *Heterodera radicicola.*

The lime and superphosphate additions were made to half of the tubs of acid soil before the tubs were planted. Two top seed pieces of Lahaina cane were put in each tub and the most vigorous resulting plant was retained. After the cane was about 14 inches high, the additions of such centipedes and snails as were available were made. The nematodes were added in the form of small bundles of well washed roots, in which free living nematodes were found to be present. The soil surrounding the stools in the nematode tubs was carefully drawn away with a trowel and the infected roots were distributed around the large feeding roots of the young cane stool, and the soil replaced. At the time we made these inoculations, we had not been able to cultivate the free living nematodes on artificial media. Our inoculations probably consisted of more than one variety of nematodes, but the method followed was the best we had available at the time.

The salt treatments were made at about the same period that we added the snails and centipedes. Each tub received the following addition of salts listed in Table I:

TABLE I

Salts Applied to Oahu Soil

Salt	Amount
Sodium Bicarbonte ($NaHCO_3$)	100.9 grams
Potassium Chloride (KCl)	10.2 grams
Sodium Chloride ($NaCl$)	59.6 grams
Magnesium Sulphate ($MgSO4.7H_2O$)	49.5 grams
Magnesium Chloride ($MgCl_2.6H_2O$)	122.4 grams
Calcium Chloride ($CaCl_2.H_2O$)	221.0 grams
	564.6 grams

In order to prevent the loss of the soluble salts by leaching, no bottom drainage was permitted, and water was added in amounts that were just sufficient to keep the soils close to optimum moisture content. The same treatment in regard to drainage and irrigation was also given to the tubs of acid soil in order to make the conditions of growth comparable in the whole set of containers.

Injury from excessive moisture which might have accumulated in the tubs during heavy rainstorms was avoided by providing sets of removable covers, made of light boards and covered with heavy roofing felt.

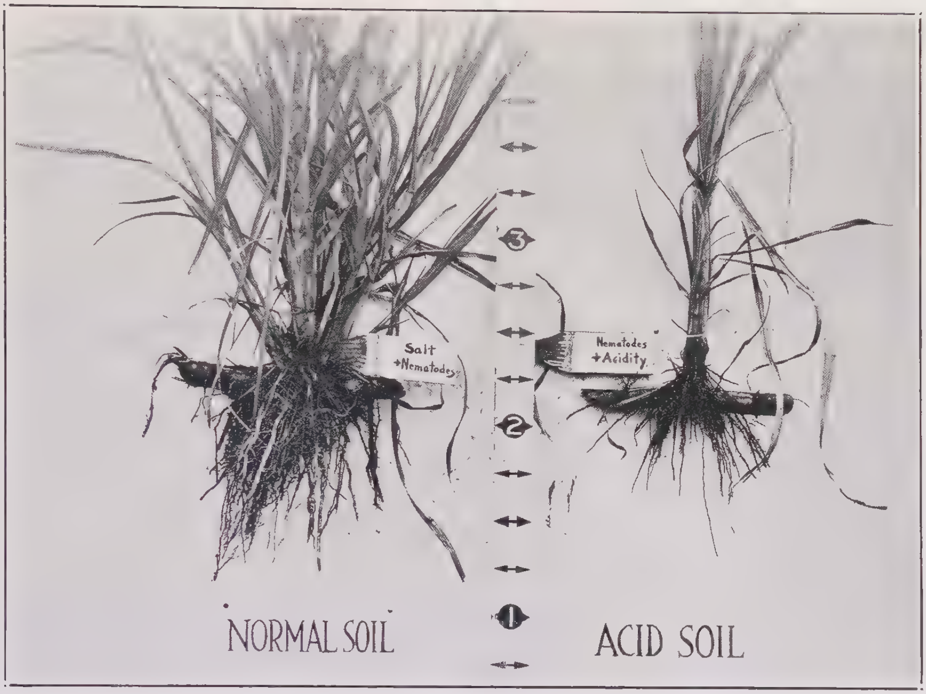
Three months after planting, the tubs were all fertilized with 45 grams of mixed fertilizer containing 11 per cent total nitrogen, 6 per cent phosphoric acid and 6 per cent potash as K_2O. This is equivalent to the application of mixed fertilizer at the rate of 1000 lbs. per acre.

At this same period it became evident that the application of the mixed salts to the Oahu soil was not causing the cane to be injured to the same extent that commonly occurs in the heavy textured lowland fields where salt accumulations usually take place. We at once made analyses to learn if the salts were possibly being washed down into the bottom of the tubs. The analytical results showed that the major portion of the salts was still in the top foot of soil. Several explanations suggested themselves. In most of the lands where salt accumulation

Full Acidity

Acidity Neutralized

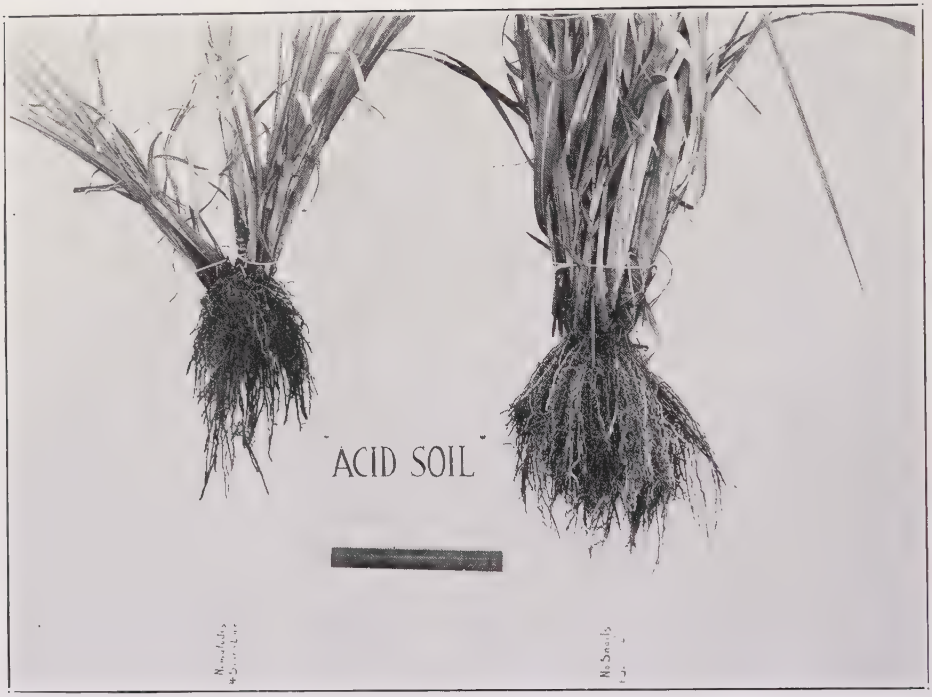
Growth of Lahaina cane in highly acid soil, after partial sterilization.



Root destruction caused by free living nematodes in a normal soil, with salts present, and in a highly acid soil.

takes place there is a notable injury to the physical condition of the soil, caused by puddling and deflocculation. The Oahu soil is an extremely open pervious silt loam, in which the salts caused no harm to the physical texture. It is also possible that much of the injury from salts may occur in field soils when the soil is rather dry and the concentration of salts in the soil solution becomes very high. We have analyzed soils from such areas where Lahaina failed in which the salts present in the soil solution amounted to 15,000 parts per million at the low concentration of 15 per cent soil moisture. The amount of salts added in our experiment would have developed an equally high concentration of salts, provided the soils had become rather dry, but this rarely, if ever, took place. In order to increase the effect of the salts, we made another addition, which was exactly one-half of the previous applications. This exerted some harmful influence, but not at all comparable to the effect which such large additions of salts have in the field. Such a result makes it appear possible that the partial sterilization had caused a sufficient biological or chemical change in the soil so that the toxic effect of the salts was reduced. This seems more probable since we had somewhat the same experience with the unfavorable acid soil. After the partial sterilization there was a notably better growth than was previously obtained in this soil.

The cane in the tubs was allowed to grow until about June 1 of this year, when it was dug up and careful observations, combined with microscopic examinations, were made of the root systems. D. M. Weller assisted us in sectioning



Comparative root and top development of Lahaina cane in a neutralized acid soil, in the presence and absence of free living nematodes.

and examining the cane roots, and J. P. Martin by working on the separation and cultivation of free living nematodes.

We found the most serious root injury had occurred where the free living nematodes were present. The stools infested with these nematodes were seriously stunted and the roots had largely disappeard in all the soil treatments. The development of roots and tops, where nematodes were present, is shown in the accompanying cuts. These are compared with cane stools growing in the normal soil with and without salt and in the acid soil, both neutralized and untreated.

The free living nematodes added to our soil cultures are a common soil inhabitant and are probably kept under control, to a certain extent, by other predatory soil nemas. Cobb (1) described three species of the genus *Mononchus*, the species of which have been demonstrated to be predaceous. In some of our cultures of nematodes, we have watched some of these attack and destroy *Tylenchus*. The presence of species of *Mononchus* may account for some of the contradictory results of experiments and field observations.

The roots of the one stool which had been inoculated with snails were badly injured but we found very few snails present. It was discovered that nematodes had been introduced into this tub, which may possibly have occurred in some traces of soil adhering to the snails. At present it is impossible to say whether the root destruction shown in the accompanying cut was due to snails or the nematodes accidentally present.

The centipedes which had been added to three tubs of cane had almost entirely disappeared. Very few remained in any of the three cultures and the roots of the stools where they had been present were almost entirely free from injuries. We are inclined to believe that the conditions were not entirely favorable for the growth of centipedes in our tubs. The ordinary cane field has more decaying organic matter present on the ground and in the soil than was found in our containers. Certain districts may be exceptionally favorable to the growth of centipedes and their free movement in the soil. This seems evident from the valuable observations of Pemberton at Honokaa. It is therefore possible that centipedes may be more injurious at times than would appear to be the case from our results.

Upon examining the uninoculated control stools we found that the roots of several of these stools were beginning to fail and decay in the soil. There were no root injuries on these stools, so it would appear that soil fungi and bacteria must also be reckoned with as an associated cause of root failure. It may be possible that the continuously moist condition of our soils was a favorable condition for these organisms.

In general we may note that toxic soil acidity and harmful concentrations of salt were not so fatal to the cane in this experiment as in ordinary field culture. This preliminary experiment clearly indicates that we must widen the scope of our investigations into the causes of root failure. Free living nematodes were associated with serious root injury. Their activities may be partly controlled, under field conditions, by other predatory nematodes. We also found that the roots of large healthy stools were beginning to fail where no injuries were present. It will require further controlled experiments before we can say definitely what relationship the various soil nematodes, fungi and bacteria, all have to root failure of sugar cane.

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Further Studies on the Saline Accumulation in Irrigated Fields

By W. T. McGeorge

This article is a continuation of our studies on the saline accumulation in irrigated fields. There is presented an experiment showing the improvement obtained in the growth of Lahaina by leaching away part of the saline material and the comparative growth of Lahaina and H 109 in water cultures containing the basic sulphates present in such soils and the basic chlorides singly and in combination. The literature covering previous work in Hawaii on this problem is reviewed, as well as certain pertinent discussions at annual meetings of the H. S. P. A., and these have been brought up to date.

In our studies on the infertility of Hawaiian soils cropped to sugar cane the complex nature of the problem was early indicated. As in many such investigations, we are rarely confronted with a single active agent, but usually find several factors of more or less importance associated. For example, in the investigation of the toxicity of our acid soils, there is convincing evidence that salts of aluminum are the principal toxic constituents of these types. No attempt was made to attribute the infertility of these acid types entirely to these salts, but rather to point out the importance which should be attached to their presence. There were found notable plant food deficiencies associated with these acid conditions. Again, it is impossible to estimate the extent of the aluminum injury, as it has been shown that in subtoxic concentrations there is a predisposition of the plant tissues to fungus invasion. At what stage the fungus enters or, in other words, the limit of chemical toxicity is difficult to establish and after identity sometimes equally difficult to correct. The actual chemical destruction of plant tissues in the field is rarely noted, as fungi and bacteria become active quite rapidly following impaired growth from chemical toxins. In other words, root injury must needs be accompanied by bacterial or fungal processes. On this basis it hardly seemed tenable to attribute to aluminum salts more than a primary predisposing role in sugar cane root or stalk rot, which condition the cane often acquires in our fields of low fertility. This same line of reasoning applies where infertility is the result of other soil conditions and any such investigation must be considered incomplete without a knowledge of the role of these organisms. In fact it is the present trend in soil chemical investigations to look upon chemical toxins as predisposing agents only. Although at certain concentrations plant growth may be entirely checked, such condition is rarely met in practice, the subtoxic concentrations being most often prevalent.

Data obtained in our study of the toxicity of aluminum salts showed that they were present only in acid soils of a certain degree of acidity which is usually found only in mauka and unirrigated fields. Many of the lowland irrigated fields may be classed as of low fertility if the failure of Lahaina in these districts may be taken as a criterion. A preliminary study of these areas along with a review of the work (10) of former members of the Experiment Station staff, as well as the observations of a number of the managers of irrigated plantations, strongly indicated that the accumulation of saline material from the irrigation water was an important growth retarding factor in these areas. In other words, that the Lahaina failure or deterioration of fertility in many of the irrigated fields is in the main a pathological or physiological condition of the cane induced in large part by the gradual accumulation of an excess of soluble salts from the irrigation water beyond the tolerance of certain varieties.

It appears from the above that we are confronted with what might be termed the "common experience" in most irrigated agricultural districts, arid or semi-arid, where surface evaporation or moisture requirement exceeds rainfall. A rise in water table usually follows extensive irrigation in lowlands. Soil water may be drawn to the surface through capillary action, there to deposit its saline content by evaporation, which material at certain concentrations is toxic toward many agricultural crops. Danger from rise in water table locally would apply mainly to the low lying fields near sea level. On the other hand, other factors may contribute to saline accumulation even in the absence of a marked rise in water table. Immediately following the draining away of the gravity water resulting from an irrigation or rain, capillary action begins to pump the water back to the surface of the soil. From this it is plainly evident that in a dry year or in the absence of occasional excessive irrigations the saline content of the soil solution within the zone of root growth will be greatly increased.

There is probably no other phase of soil infertility which has been more extensively or intensively studied than the alkali problem. The literature covering these investigations is legion and in the main shows the toxicity of the saline accumulations to be proportional to the concentration in the zone of root activity. The nature and ratio of the saline combinations are also governing factors. Unfortunately, it is not possible to foretell with any degree of certainty the subtoxic concentration of alkali in soils. This is in large measure due to soil variability and a lack of knowledge of the physiological effects of the so-called alkali salts and the widely variable ratios which are possible in the soil solution, that is, the salt-plant ratio as well as the soil-salt-plant relationship. We know that a high concentration of saline material entirely restricts plant growth and that small amounts are essential. In the intermediate concentrations, from which arise the varying degrees of toxicity, numerous physiological disturbances are possible and it is these with which we are concerned. The difficulty in definitely identifying the principal growth retarding factor is apparent. The per cent alkali in soils tells us little about how plants will be affected. It is the strength and nature of the soil solution in which the roots are bathed which concerns most. The physical or mechanical condition of the soil induced by or accompanying the saline accumulation is also a factor in the fertility of these types which makes

more difficult any estimation of their fertility. Island soils in which excessive accumulations have taken place can usually be immediately identified by their highly adhesive properties or "sticky" texture.

The writer believes that one of the big problems in the study of soil fertility on Island irrigated plantations involves the accumulative tendency of saline material from artesian irrigation water and its effect upon the soil and growth of cane. There has unquestionably been, in the past, a notable accumulation in some fields. Is it not better, therefore, that our investigations precede rather than await such time as the fertility of these fields is greatly impaired, assuming that such may in time occur?

Plan of Investigation

As a means of investigating the role which saline accumulation played in the failure of Lahaina, the following line of study was taken up:

1. To remove the actual soil solution by displacement from a representative number of irrigated soils and to determine by analysis the composition of these.
2. To determine the effect on plant growth of reducing the soluble saline content by leaching these soils.
3. To study by water and sand cultures the toxicity of the salts found in the above analyses toward sugar cane, comparing Lahaina and H 109 varieties.

Review of Literature

Often in alkali soils some one class of salts will predominate. Thus we have sulphate alkali, carbonate or "black" alkali and chloride alkali. Sulphate alkali is generally considered the least harmful toward plant growth. In most of the soils thus far examined by the writer, chloride salts are in excess and it is in the physiological effects of this class on sugar cane that we are most interested here. There has been considerable work done on the action of chloride salts upon plant growth and, as above stated, there has been found a lesser tolerance than for sulphates. In fact a number of investigators go so far as to condemn the use of chloride (muriate) of potash on this basis. Experimental evidence is not lacking, confirming this contention as applied to some crops, which of course is not true for all.

Loew (7) found that calcium and magnesium chlorides have an injurious effect on plants probably on account of the liberation of hydrochloric acid in the cells, this not being assimilated like sulphuric and nitric acids and therefore accumulating to a noxious degree.

Wheeler and Hartwell (18) found calcium and ammonium chlorides to exert a marked poisonous action on certain plants.

Tottingham (17) says: "It is certain that some seed plants contain much more chlorine than others; that some may endure much higher chloride concentration about their roots than others and that differences in the amount of this element in the soil are frequently accompanied by characteristic differences in development and growth. The species of plant, type of soil, and the complex of factors considered as climate, greatly influence the effects."

In Utah, where extensive accumulations of sulphates and chlorides have been found in soils, Harris (5) found that "the anion or acid radical and not the cation or basic radical determines the toxicity of the alkali salt. Of the acids used the chlorides were decidedly the most toxic, while sodium was the most toxic base." He gives the chlorides in the following order of toxicity: sodium chloride, calcium chloride, potassium chloride and magnesium chloride.

Harter (6) has shown that plants grown in saline solutions undergo modifications of structure which reduce transpiration. Increase in thickness of cuticle and a deposit of wax upon the leaves results from excess of soluble salts. The absorbing capacity of the roots is checked, creating a physiological drought. In other words, the physiological changes in the plant are due to attempts to reduce the rate of transpiration. It is of interest to mention at this point that this same condition was often noted in the so-called Lahaina disease on the irrigated plantations.

Loew (8) has noted in the presence of injurious concentrations of sodium chloride a retardation of the assimilation processes in leaves, a reduction in chlorophyl and a decrease in sucrose content of sugar beets.

In India, Row (16) has given some attention to the growth of sugar cane on saline land. He found sodium chloride to be the principal growth retarding salt and showed that an excess of this salt increased the chlorine content of the juice and lowered the juice purity, sucrose and glucose content. He says that thick juicy cane varieties will not come up at all in saline land, while the thin, less juicy varieties are less affected by the salt.

Reed and Haas (15) working on orange trees found that large amounts of chlorides cause tip burn and abscission of leaves and death of young shoots. Sodium chloride restricted root growth and death of old leaves in concentrations greater than 1,000 parts per million. Calcium chloride increased growth of roots and tops up to 3,000 parts per million, although slight injury was caused by the highest concentration. Orange trees growing in saline soils were greatly benefited by leaching.

No attempt is made at completeness in the preceding review of the literature, but rather it is the intention to stress the generally recognized property of chlorides in retarding plant growth. A large amount of work has been done on the toxicity of chlorides as single salts, under which conditions it is an easy matter to determine the toxic range. The problem becomes complex when one attempts to reproduce soil conditions, as here we encounter an almost indeterminable array of several salts present in widely variable ratios. As the question of saline accumulation and its relation to plant growth is by no means a new subject in the Islands, it is of interest to review in some detail the previous work of members of the Experiment Station staff on account of its direct bearing on our present observations.

Early attention was given to saline soils by Maxwell (9). He noted some localities sufficiently contaminated by sea water as to be destructive to vegetable life. In most instances he says the deleterious agent is common salt; in others there is a mixture of common salt with the chlorides of calcium and magnesium. He says the latter are the most injurious to plant life and in the lowlands lying

almost level with the sea where there are no means of getting these salts removed, their impregnation renders the soil useless. The following data published by him show some effect of the salt on sugar cane:

SALT IN HAWAIIAN SUGAR LANDS AND ITS EFFECT UPON SUGAR CANE

Soil No.	Location	Per Cent Salt in Soil	Condition of Cane
1	Highlands	.061	Normal
2	"	.063	"
3	"	.050	"
4	"	.059	"
5	Lowlands	.129	Not wholly healthy
6	"	.130	Not wholly healthy
7	"	.155	Quite healthy and normal
8	"	.181	Yellow color
9	"	.181	Yellow color
10	"	.460	Small, yellow, stunted
11	"	.832	Cane white and dying
12	Sea bluff land	.223	Leaves bleached, cane small

From the above he concluded that soils containing over .15 per cent salt, unless a liberal allowance is made of some element to force on the growth, the sugar cane is liable to suffer.

Further data which he presents are of interest and include the yield of three parts of one field which contained different amounts of salt in the soil. The soil in other respects was identical:

EFFECT OF SALT ON GROWTH OF CANE

Field	Salt in Soil Per Cent	Yield of Sugar per Acre in Tons
First part	.10	6.0
Second part	.45	1.5
Third part	1.00	0.0

In order to show the sensitiveness of sugar cane to salt and the ease with which the plant takes it up, he presents the following:

EFFECT OF SALT ON SUGAR CANE

Condition of Water	Salt in Water Per Cent	Salt in Cane Juice Per Cent	Condition of Cane
Slightly brackish	.125	.470	Growing
Highly brackish	.223	.714	Dying

He comments as follows: "In the above example the soils contained the same amounts of salt, about .15 per cent, which is too high to come in contact with even the slightly brackish water without detriment to plants. The extreme sensitiveness of sugar cane to salt content of water is made very clear. From our present experience the danger point should be placed at .14 per cent or 100 grains per Imperial gallon."

Additional work on this problem was done by Eckart (3) which, along with a number of calculations, is of interest. As an example he took a plantation using 2,500,000 gallons of water per acre per crop, which water was found to contain 125 grains salt per U. S. gallon. With such an irrigation goes 44,642 lbs. of salt during the growth of one crop. If the land in question was not irrigated to a point above saturation practically none of this water would drain off and the salt would remain in the soil. On the plantation in question the salty water was having no apparent effect upon the cane. The manager did not feel that he was using an excess of water because if he decreased the amount applied the cane suffered. Eckart questioned whether it was a case of too little water or too much salt accumulation in the surface areas resulting from insufficient water to leach the salt to lower levels. He offered the suggestion that the cane in this case suffered from accumulated salt and not lack of water.

Eckart's work (2) on the effect of saline water on the soil and cane is also of interest. He showed experimentally that saline water passes through the soil quite rapidly, provided an outlet for subdrainage is at hand, and carries with it large amounts of lime, potash and magnesia. Thus he showed a tendency toward a preponderance of basic sodium through a replacement of the other bases or an establishment of a saline equilibrium. Heavy rains and excessive irrigations only can prevent the saline accumulation, but he emphasizes that with this must go large quantities of calcium, magnesium and potash. He determined the relative toxicity of these salts by tub experiments. In these he showed the toxicity quite conclusively, depending, however, on the rate and quantity of irrigation water applied as well as the nature of the soil. From this work he concluded that when occasional excessive irrigations are applied to cane growing in tubs (constructed so as to allow free drainage), the use of irrigation water of high salt content only checked in a small measure the growth of the cane. Without the excessive irrigations the cane died. He also showed that large quantities of lime were liberated and that the calcium chloride formed was less toxic than sodium chloride.

He next conducted these experiments on a field scale (4), which yielded even more convincing data. The tables showing the effect of saline irrigation upon the quality of the juice and yield of cane are of considerable interest and are reproduced below:

QUALITY OF JUICE

Salt per Gallon of Water	Brix of Juice	Sucrose of Juice	Glucose of Juice	Purity Juice	Gums Juice	Chlorine Grains per Gallon of Juice	Salt Grains per Gallon of Juice
None	20.28	18.90	.312	93.20	.43	9.8	16.17
200 grs.	16.46	14.40	.264	87.50	.53	93.1	153.63
200 grs.	16.56	14.50	.271	87.60	.56	84.9	140.17
200 grs.	15.89	13.80	.280	86.80	.50	105.2	173.67

YIELD OF CANE AND SUGAR PER ACRE

Salt Per Gallon of Water	Lime Added	Cane per Acre, Lbs.	Sucrose in Cane per Cent	Sugar per Acre, Lbs.
None	No lime	151,675	16.91	25,648
200 grs.	G. coral	42,311	12.88	5,449
200 grs.	Gypsum	42,108	12.97	5,461
200 grs.	No lime	30,085	12.35	3,715

He comments on the above as follows: "The difference in yield of cane and sugar was remarkable. As for the effect on the quality of the juices, the juice of the cane receiving saline irrigation was characterized by lower density, less sucrose and glucose, lower purity and a much larger concentration of salt than the juice from the cane receiving fresh water." Extra irrigation tended to materially increase the yield and quality of the cane.

Some experiments started by Blouin (1) in 1901 and continued to 1903 are also of interest. In these experiments amounts of salt in the irrigation water were varied from 50 to 200 grains per U. S. gallon. The data showing the yields of sugar and cane per acre and quality of juices are given in tabular form and are reproduced below:

IRRIGATION WITH SALT WATER

Salt per Gallon of Irrigation Water	Salt Added per Acre per Crop	Cane Yield per Acre in Lbs.
50 grains per gallon	14,159	135,675
100 grains per gallon	28,318	92,754
150 grains per gallon	42,477	102,744
200 grains per gallon	56,636	79,860

ANALYSES OF JUICES

Salt per Gallon Irrigation Water	Brix	Sucrose per Cent	Glucose per Cent	Purity	Chlorine per Cent	Chlorine Grains per Gallon Juice
50 grains	19.79	18.1	.249	91.46	.0520	30.212
100 grains	20.07	18.3	.219	91.18	.0758	44.04
150 grains	18.89	17.0	.281	89.99	.0778	45.086
200 grains	18.07	16.35	.534	90.42	.1010	58.681

YIELDS PER ACRE

Salt per Gallon Irrigation Water	Cane per Acre	Sucrose in Cane per Cent	Suger per Acre
50 grains	135,675	16.2	21,979
100 grains	92,754	16.38	15,193
150 grains	102,744	15.22	16,638
200 grains	79,860	14.63	11,684

These tables show a close relation between the salt content of the irrigation water and yield of cane and sugar. Also, there was a steady decline in purity of juice with increase in salt, and along with this there was noted a drop in density and sucrose but a material increase in glucose.

Peck (13) has shown that the chlorine content of molasses is related to the source of the cane. It varied from .644 to 3.277 per cent, the lowest figure being obtained on molasses from unirrigated plantations. The more brackish the water, the higher the chlorine content of the molasses.

Composition of the Soil Solution

Taking the Lahaina failure as an indicator of infertility, a series of soil samples was collected from irrigated fields on the island of Oahu to study the composition of the soil solution. These samples were taken from areas where Lahaina was still growing or where it had previously failed. This phase of the investigation has already been published (10) and will not be repeated here. Suffice it to say that it showed unmistakable evidence of a large accumulation of saline material in many irrigated fields and a low vitality in Lahaina cane as compared to some other varieties notably H 109 and Yellow Caledonia when grown under such conditions. The chlorides were in all cases in excess of sulphates. Sodium, except in one case, was in excess of calcium, magnesium and potassium, while calcium was in greater concentration than magnesium. A rapid decrease in chlorides as a result of the winter rains was shown in this data.

These analyses have been recalculated to show the ratio of sodium, calcium and magnesium in the soil solution and also that of sulphates and chlorides. In these calculations magnesia was taken as 1 in the ratio of bases, while SO_3 was taken as unity in the SO_3 : Cl ratio.

TABLE 1

Ratio of Acid and Basic Radicals

Soil No.	MgO	Na_2O	CaO	SO_3	Cl
1	1	1.63	2.33	1	6.43
3	1	6.47	1.10	1	15.00
4	1	2.20	1.20	1	2.20
5	1	....	1.06	1	6.50
6	1	2.30	1.01	1	5.0
7	1	3.40	1.30	1	8.0
8	1	4.60	1.30	1	1.9
9	1	3.00	2.20	1	4.5
14	1	3.60	1.00	1	0.85
15	1	5.20	1.50	1	3.30
16	1	2.55	1.60	1	0.81
17	1	2.70	1.50	1	3.00

This table shows that it is not entirely a question of ratio of either basic or acid ions independent of concentration, but rather principally the latter. It is of interest to note the consistency of the magnesia-lime ratio in these soil solutions and the wide variation in the ratio of sodium to calcium and magnesium.

Leaching Experiments

Having shown in the study of the soil solution the higher concentration of saline material in the fields in which Lahaina grew with least vigor, our next

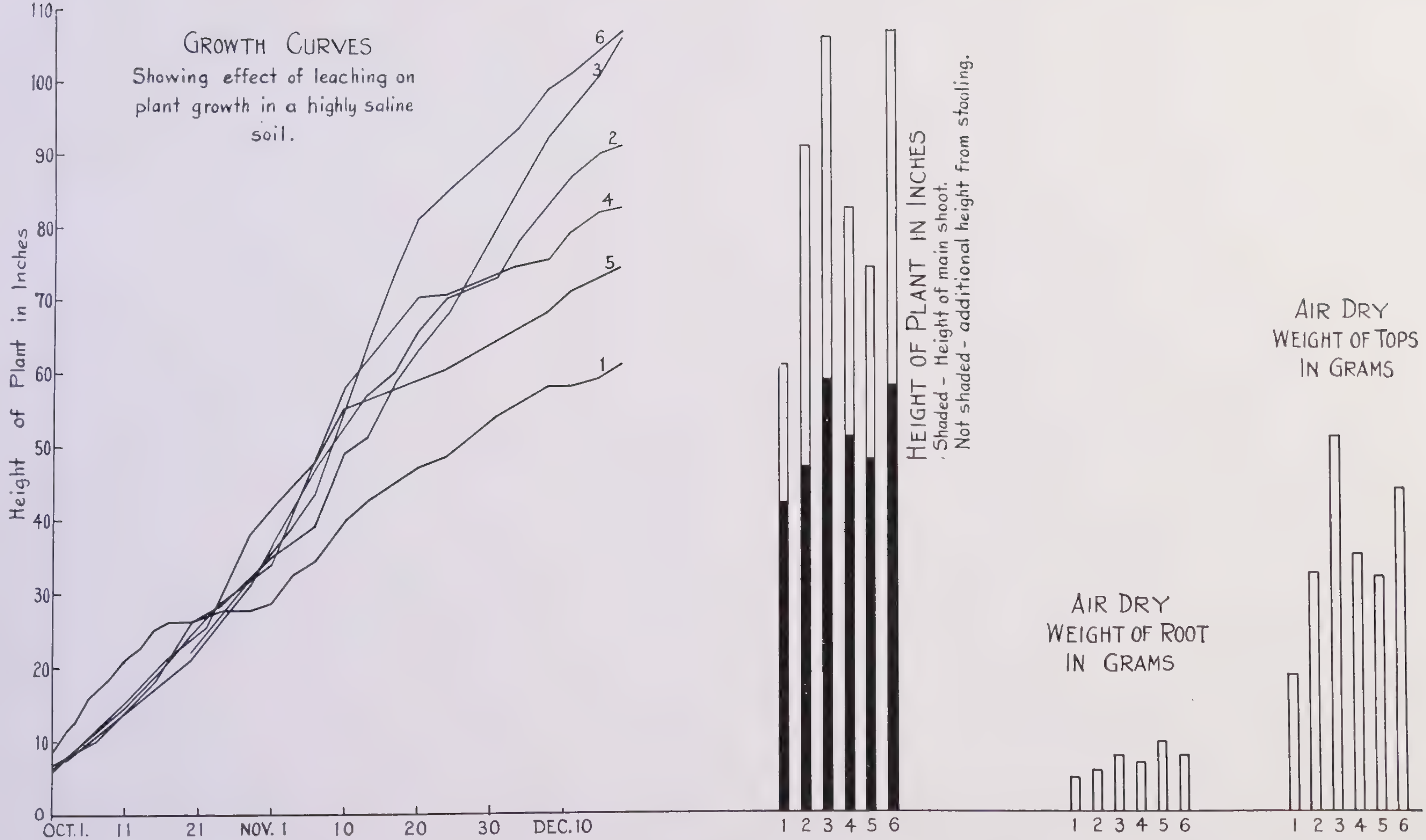
GROWTH CURVES
Showing effect of leaching on plant growth in a highly saline soil.
Height of Plant in Inches
0
10
20
30
40
50
60
70
80
90
100
110
OCT.1.
11
21
NOV. 1
10
20
30
DEC.10
1
2
3
4
5
6
HEIGHT OF PLANT IN INCHES
Shaded - Height of main shoot.
Not shaded - additional height from stooling.
AIR DRY
WEIGHT OF ROOT
IN GRAMS
AIR DRY
WEIGHT OF TOPS
IN GRAMS

Fig. 1

step was to show the effect of leaching such a soil upon the growth of Lahaina. With the exception of black alkali (sodium carbonate) the other alkali salts may be leached from soils with comparative ease by excessive irrigation. With this in mind a quantity of soil was obtained from such a field, placed in tubs (40 lbs. soil per tub) and the following series of treatments were carried out:

1. Unleached soil was placed in the tub just as obtained from the field.
2. Four gallons of water were added, equivalent to 2,000,000 gallons per acre per crop or one crop's irrigation.
3. Same treatment as 2 except 8 gallons of water, equivalent to 2 crops, were used.
4. Twelve gallons equivalent to 3 crops.
5. Sixteen gallons equivalent to 4 crops.
6. Twenty gallons equivalent to 5 crops.

The water was applied at the rate of 2 gallons per day, allowed to stand over night and then drained off by subdrainage. This was continued daily until each treatment had received its full application of water. The leachings were collected, measured and aliquots taken for analysis in order to determine the amount and composition of the saline material removed.

Effect of Leaching on Growth: Each pot was planted with one Lahaina seed (three-eye seed with two eyes pinched out) on September 18, 1924. Growth measurements were taken of the plants beginning October 1, and continuing to December 18. These results are shown graphically in Fig. 1. This figure shows the rate of growth, final height of main shoot plus additional growth from stooling, and final dry weight of roots and tops. These show very clearly the increased fertility obtained on removing the excess of saline material, and show that saline accumulation is a growth retarding factor in this soil.

Unfortunately, this soil is a very heavy clay, the particles of which have been greatly deflocculated by the saline material. The heavy leaching treatment given in this experiment greatly increased this puddled condition, thus checking the growth in the pots from which the salt had been leached. At the completion of the experiment the soil in the unleached pot was in a much better mechanical condition than the others, although poor itself. The soil particles in all pots were so closely cemented as to make it impossible to remove the roots intact for photographing.

The relation of climatic factors to toxicity of saline accumulation was also strikingly brought out in this experiment. On sunny days the leaves on the plant in the unleached pot were badly curled, as if suffering from drought, when as a matter of fact the soil was practically saturated. This characteristic curling was entirely absent in the pots receiving the heaviest leachings, and rarely noted in treatments 2 and 3.

From October 16 to November 1 there was very little additional growth in the check, after which renewed growth took place. This was due to a series of sunny days up to November 1, after which a month of cloudy and rainy days set in. Attention is called to the relation of such changes to the physiological effects of high saline concentrations. There is less toxicity where the rate of

Fig. 2. Left to right: 1. Check—soil not leached. 2. Soil leached with one crop's irrigation. 3. Soil leached with one crop's irrigation.

transpiration is lowered by cloudy days, which is in agreement with the general observations on alkali lands. A high rate of transpiration such as takes place on dry, sunny days rapidly exhausts the plant vitality by a high rate of saline absorption in supplying the moisture passing through the plant and evaporating from the leaves. On December 18 the plants were transferred to the shelter of a greenhouse where, other than being stunted in growth, there was less outward appearance of toxicity than when grown in the open. The comparative growth of the plants is shown in Fig. 2.

It seems fair to interpret these observations as indicating that the growth of Lahaina cane will be greatly enhanced by the removal of accumulated saline material; and, further, that the concentration of salts in some irrigated fields has already reached sufficient accumulation as to seriously retard the growth of the Lahaina variety.

Mineral Composition of Plants: The roots and tops from these plants were analyzed separately in order to note the effects of saline material on the inorganic constituents of the plant. The results of the analyses are given in the following table as per cent of ash and as per cent of dry (water free) material:

TABLE 2

Composition of Tops in Per Cent Dry Matter

Pot No.	Ash	Silica SiO_2	Iron and Alumina $Fe_2O_3Al_2O_3$	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Chlorine Cl	Phosphoric Acid P_2O_5	Sulphur Trioxide SO_3
1	8.99	2.41	.37	.79	.85	.39	1.77	.70	.68	.55
2	8.40	2.23	.37	.55	.58	.41	1.83	.62	.63	.59
3	8.65	3.16	.36	.46	.53	.30	1.95	.65	.67	.55
4	7.72	2.97	...	.48	.52	.31	1.74	.51	.56	.49
5	8.53	3.36	.36	.44	.50	.64	1.42	.52	.63	.49
6	8.31	3.33	...	.42	.59	.24	1.89	.52	.58	.54

Composition of Roots in Per Cent Dry Matter

Pot No.	Ash	Silica SiO_2	Iron and Alumina $Fe_2O_3Al_2O_3$	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Chlorine Cl	Phosphoric Acid P_2O_5	Sulphur Trioxide SO_3
1	9.30	2.52	...	1.19	.54	1.03	.31	.40	.51	.66
2	7.66	2.47	2.22	.67	.42	.60	.55	.10	.64	.57
3	....	....	1.50	.70	.35	.48	.40	.04	.61	.41
4	7.75	2.27	2.44	.63	.43	.56	.73	.04	.55	.45
5	10.86	3.82	2.33	.61	.37	.52	.41	.02	.49	.47
6	7.32	2.72	2.17	.59	.35	.38	.49	.04	.55	.46

Composition of Ash in Per Cent Ash Tops

Pot No.	Ash	Silica SiO_2	Iron and Alumina $Fe_2O_3Al_2O_3$	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Chlorine Cl	Phosphoric Acid P_2O_5	Sulphur Trioxide SO_3
1	....	26.42	4.08	8.66	9.30	4.28	19.43	7.93	7.46	6.02
2	....	26.20	4.40	6.42	6.86	4.83	21.45	7.50	7.44	6.91
3	....	36.24	4.09	5.22	6.04	3.47	22.30	7.60	7.70	6.29
4	....	37.80	....	6.11	6.55	3.96	22.16	6.80	7.09	6.31
5	....	39.07	4.15	5.11	5.79	7.45	16.50	6.18	7.33	5.67
6	....	40.05	....	5.00	7.08	2.84	22.65	6.28	6.99	6.45

Composition of Ash in Per Cent Ash Roots

Pot No.	Ash	Silica SiO_2	Iron and Alumina $Fe_2O_3Al_2O_3$	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Chlorine Cl	Phosphoric Acid P_2O_5	Sulphur Trioxide SO_3
1	....	25.86	.....	12.23	5.58	10.55	3.24	4.52	5.28	6.83
2	....	31.22	28.10	8.58	5.32	7.69	6.92	1.40	8.08	7.18
3	....	.....	29.44	13.71	6.85	9.51	7.83	.66	11.96	8.04
4	....	28.16	30.22	7.79	5.32	6.94	9.12	.51	6.84	5.56
5	....	34.40	.....	5.53	3.31	4.70	3.69	.20	4.45	4.23
6	....	36.00	28.60	7.88	4.67	4.98	6.43	.54	7.29	6.07

Ash: With one exception, the ash or total mineral matter absorbed by the plant was less in the plants grown on the leached soils.

Silica: There is no difference in the amount of silica absorbed as per cent dry matter. On the other hand, on the basis of total mineral matter or ash present in the plants there is a greater ratio of silica in the ash of plants grown on leached soils.

Iron and Alumina: These elements show no consistent variation.

Lime and Magnesia: Lime and magnesia were taken up by the plant in decreasing amounts with increase in amount of water used in leaching, showing the high absorption of these elements probably as chlorides when a high concentration is present in the soil solution.

Sodium: The effect of sodium upon the mineral balance of the cane is shown principally in the roots. Here there is a very high absorption of sodium, which is materially reduced by leaching the soil. There is no consistent relation in the sodium content of the tops, indicating that calcium and magnesium chlorides may be the primary toxic agents in the above-ground parts of the plant. Other analyses which we have made have shown that it is characteristic of sugar cane to retain the largest amount of sodium in the roots, while potash is present in excess in the tops.

Potash: Here, again, the principal variation is in the roots, where increased absorption of calcium, magnesium and sodium has materially reduced the absorption of potassium in the unleached pot, while leaching the soil had the effect of increasing the absorption of potash. In other words, calcium, magnesium and sodium tend to retard potash absorption when present in excess. It is of interest to state that the field from which this soil was obtained responds markedly to potash fertilization.

Chlorine: The amount of chlorine absorbed by the plant is greatly reduced by leaching the soil, and, as shown in the illustrations, the growth of cane was very greatly benefited thereby.

Phosphate and Sulphate: There is no consistent relation in the phosphate absorbed. As for the sulphate content of the plants, the per cent dry matter shows a higher absorption by the roots in the unleached soil but no difference in the tops.

Mineral Matter Removed from the Soil by Leaching: The soil solution as removed from this soil by the displacement method was found to contain 14,408 parts per million solids with 5,388 parts per million chlorine. This is equivalent to practically 30 per cent of the total mineral matter and means that the plant roots would be bathed in practically an N/7 solution of salt at this moisture content. The per cent moisture in the soil used for the removal of the soil solution was 14 per cent and only slightly below what it would be under field conditions for this type.

The leachings from all pots were collected, well mixed and aliquots taken for analysis. The results are given in the following table:

TABLE 3

Composition of Drainage Water in Parts per Million

Pot No.	Total Solids	Silica SiO_2	Lime CaO	Mag. MgO	Soda Na_2O	Potash K_2O	Sulphur Trioxide SO_3	Chlorine Cl
1				not leached				
2	4178	23	531	279	506	43	588	1220
3	2692	23	338	180	463	30	360	768
4	1580	..	189	109	289	13	194	432
5	1358	20	172	95	279	15	186	372
6	1636	22	183	101	318	13	164	484

Amount of Each Element Removed per Pot by Leaching, Results in Grams

Pot No.	Total Solids	Silica SiO_2	Lime CaO	Mag. MgO	Soda Na_2O	Potash K_2O	Sulphur Trioxide SO_3	Chlorine Cl
2	39.7	.2	5.0	2.6	4.8	.4	5.6	11.6
3	60.6	.5	7.6	4.0	10.4	.7	8.1	17.3
4	58.5	..	7.0	3.9	10.7	.5	7.2	16.0
5	62.4	.9	7.9	4.4	12.8	.7	8.5	17.1
6	94.9	1.3	10.6	5.8	18.4	.7	9.5	28.1

After harvesting the plants in the pots the soils were analyzed for water soluble constituents by extracting one part soil with five parts water. It was the original plan to make analyses of the soil solutions obtained by displacement, but the soils were so badly puddled and in such a bad mechanical condition that it was impossible to pack it properly in cylinders. The results of these analyses are given in the following table:

TABLE 4

Composition of Water Extracts Calculated to Parts per Million Dry Soil

Pot No.	Total Solids	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Sulphur Trioxide SO_3	Chlorine Cl
1	3122	373	206	587	60	513	813
2	1264	127	63	311	38	184	177
3	1099	104	43	276	43	122	98
4	1101	110	64	226	45	103	103
5	1040	104	52	227	32	71	104
6	985	104	55	246	36	73	98

Table 3 shows the large amount of leachable material in this soil. It is composed in the main of the chlorides and sulphates of sodium, calcium and magnesium, with the former in excess.

The analyses of the water extracts of the soils at the end of the experiment show a remarkably constant composition in the soils which had received the equivalent of 2, 3, 4 and 5 years' irrigation. This agrees with the growth measurements obtained in the pot experiments, where it will be noted there was little or no increase in plant growth beyond the 2-year irrigation. This is undoubtedly due to the poor mechanical condition of this soil type and the treatments would probably have shown a higher extraction of saline material in a more porous soil.

Further discussion of the composition of the soil solutions and the data obtained in the leaching experiment is of interest at this point. It was found on studying the soil solution (10) that in ten cases out of eleven, sodium was in excess of calcium and magnesium, while in one case, that of the highest saline accumulation, calcium was in excess. In all cases except two (well drained soils) chlorides were in excess of sulphates. And further, in all cases calcium was in slight excess over magnesium.

The excess of calcium in the soil solution of highest concentration is of more than passing interest. It shows that calcium chloride is the most soluble salt present in these soils; that it will be most readily leached to the lower strata and is the slowest in returning to the soil surface during periods of evaporation. The downward movement of water through the pore spaces is much more rapid than the upward movement by capillarity, and therefore in the former will carry in excess the more soluble calcium chloride. The salts carried to the surface by capillarity and deposited as a crust by evaporation are in greater equilibrium, and will therefore carry less calcium chloride in proportion. Over an extended drought, however, or during the dry summer months if the soil surface is exposed, the soil moisture becomes saturated in the upper layer, resulting in the precipitation of the less soluble salts, notably calcium sulphate. There results from this a concentration of the chlorides of calcium and sodium, more especially the former. The correctness of this contention is further demonstrated in the composition of the leachings from the pot experiment, in that the first leachings show an excess of calcium chloride over sodium chloride, while in continued leachings this is changed to an excess of sodium chloride.

It is of interest to state that in some cases the growth of Lahaina on these soils has been improved somewhat by gypsum, which would tend to reduce the conditions above described. That is, a reaction between the calcium sulphate and sodium chloride would yield calcium chloride as one of the end products which would be more rapidly leached by the rains and irrigation water.

Further evidence of the presence of calcium chloride is shown by the "sticky" texture of the saline areas, this salt tending to retain for a longer period a saturated moisture condition. The highly hygroscopic properties of calcium chloride preclude its ever being deposited in the surface crust of salt, but rather to be present in a high degree of concentration in the soil solution.

Sand and Water Cultures Showing the Effect of Chlorides and Sulphates of Sodium, Calcium, Magnesium and Potassium on Lahaina and H 109 Varieties

In planning a series of water cultures it was necessary to run a preliminary experiment using concentrations covering a wide range in order to select a more restricted range for closer cultural study. This was necessary because of our lack of knowledge of the toxicity of these salts in pure culture. The highest concentration noted in our examination of the concentration of the soil solution from the field was approximately 6,000 parts per million chlorine or .2 to .1 normality. The culture solutions for the preliminary experiment were therefore made

up as .2, .1, .05, .02, .01 and .004 normality for the sodium chloride, magnesium chloride, potassium chloride, sodium sulphate and magnesium sulphate while the same were used for calcium chloride except that there was added a .4 normal solution, and the .004 normal solution was omitted.

As containers for growing the plants, one-half gallon glass percolators were used. These were filled with silica sand and an outlet allowed in the bottom of the percolator for the drawing off of the nutrient solution at varying periods (weekly), when fresh nutrient was added. Cane shoots were prepared by growing from seed pieces to a height of approximately ten inches, at which time they were cut from the seed piece and placed in the sand cultures with about one-half inch of the base below the surface. As a basic nutrient to which the salts were added, the following was used in this and the following experiments:

.2 normal calcium nitrate	15 cc. per litre
.1 " ammonium nitrate	10 " " "
.1 " potassium chloride	8 " " "
.2 " magnesium sulphate	8 " " "
8.3 grams per litre calcium phosphate	5 " " "
Ferric citrate	trace

The shoots were planted on December 19, two Lahaina and two H 109 in each percolator. Observations of the progress of the experiment were made from time to time, some of which are of interest.

December 30—Sodium Chloride Cultures: This salt appears to cause more distinctly rolled leaves, less bleaching, or chlorosis in high concentrations, but rather a brown, wilted condition, beginning at the tip of the leaves in Lahaina. With H 109, wilting is almost without loss of color in the higher concentrations, and where chlorosis does appear it occurs only along the tissues carrying the smaller vascular bundles, as in the yellow or bleached striping of Pahala blight.

Magnesium Chloride Cultures: The effect of the magnesium chloride is shown in a more solid, uniform bleaching of the leaves with no appearance of striping. This form of chlorosis is an exact reproduction of the chlorosis often noted in young shoots from stubble in many Oahu fields. In the highest concentrations the plants wilted without any development of chlorosis.

Calcium Chloride Cultures: In the stronger concentrations there is a notable wilting. At lower concentrations, .01 normal, the chlorosis takes the form of a stripe, such as described under sodium chloride.

In later observations, similar conditions as above described were noted. The experiment was continued to January 27, at which time the plants were removed and observations made on the roots as well where the plants were still alive. Detailed observations are omitted because these will be taken up in the experiments to follow. In general, speaking of the plant as a whole, there was indication of a greater resistance to chlorides in the H 109 as compared to Lahaina. This was shown principally in the length of time preceding appearance of toxicity in the shoots following their planting in the culture solutions. H 109 was by no means immune, but rather shows notable saline toxicity under the conditions of this experiment, which may not hold true under soil conditions.

The sulphate cultures gave somewhat similar results in that there was notable toxicity in high concentrations and less resistance in Lahaina as compared to H 109. In this series little or no chlorosis developed and there was an entire absence of the striping of the leaves, as shown in the chloride cultures.

On the basis of this preliminary experiment a range of concentration varying from 500 to 4,000 parts per million chlorine was selected. It appeared to be the better plan to have all cultures containing equal parts of chlorine from the different bases. For this, stock solutions containing 100 grams chlorine per litre were made up of sodium chloride, magnesium chloride, calcium chloride and potassium chloride. Also, solutions of sodium sulphate, magnesium sulphate and potassium sulphate were made up containing 100 grams of SO_4 per litre. From these, by proper dilution, five different concentrations were used, each containing the nutrient solution previously described, and were as follows:

1. Nutrient solution plus 4,000 parts per million chlorine.
2. Nutrient solution plus 3,000 parts per million chlorine.
3. Nutrient solution plus 2,000 parts per million chlorine.
4. Nutrient solution plus 1,000 parts per million chlorine.
5. Nutrient solution plus 500 parts per million chlorine.

A similar series was prepared for the sulphates, except that the most dilute, namely, 500 parts per million, was omitted. Also, a set of cultures was prepared in which the three chlorides, calcium, magnesium and sodium were combined in the same ratio as found in the analysis of the soil solution from the soil used in the pot experiment.

The Lahaina and H 109 shoots were prepared as previously described. The plants were grown in 250 cc. wide mouth bottles, wrapped in black paper, and the nutrient solution changed once each week. The original height of the shoot used materially influences the results obtained in comparative toxicity studies. For this reason, while it was not possible to obtain all shoots on the same day, they were all selected of as nearly the same height as possible. It was originally intended to carry the Lahaina and H 109 plants at the same time, and seed pieces were planted accordingly for obtaining the shoots. The H 109 failed to germinate in sufficient number to supply the requirements, so that it was necessary to to carry the experiment in two parts. The Lahaina shoots were started March 2-6, and the H 109 April 30 to May 4. The experiments were carried out in two duplicate sets, in one of which the roots were germinated in tap water and grown to a length of one-half to one inch before placing in the chloride culture. In the second the shoots were started immediately in the culture solutions, or before the roots had germinated. All photographs show plants after having grown for one month in the culture solutions.

Sodium Chloride Cultures: Four days after placing the Lahaina shoots in the sodium chloride cultures the effect was apparent both in the chlorotic appearance of the leaves and a crooked or "hooked" root system in all except the solution containing 500 parts per million chlorine. In the same period of time there

was little or no appearance of chlorosis in H 109, and far less crooked roots, but stunted growth was evident as compared with the control. H 109, in other words, failed to show the outward appearance of the effect of this salt as did the Lahaina. The condition of the plants at the end of the one month period is shown in Figs. 3 and 3A. At 4,000 parts per million H 109 made better growth of both roots and tops. There is little difference at 3,000, 2,000, 1,000 and 500, as far as can be shown by photograph, other than the drooping tops in the Lahaina and the better top growth of Lahaina at 1,000 and 500 p.p.m. On the whole, there was less top injury in Lahaina and less root injury in H 109. The secondary roots were longer on the H 109 plants. At the one month period a chlorotic condition was quite noticeable in the H 109 plants, showing itself in the form of a bleached condition in stripes along the smaller vascular bundles in the leaves.

Calcium Chloride Cultures: In the calcium chloride cultures a disturbance was noted in the 4,000, 3,000 and 2,000 p.p.m. cultures on the Lahaina plants, as shown by chlorosis and crooked roots. In the same period of time no disturbance was noted in the H 109 except in the strongest concentration. As in the sodium chloride cultures the H 109 showed less chlorosis throughout. On the other hand, in the calcium chloride the H 109 showed the earliest distress. At the end of the one month period, at which time the plants were photographed, Figs. 4 and 4A, H 109 had made the better growth in the highest concentrations, and notably better root growth in the lower concentrations. Chlorotic leaf stripes were present on the plants in the 4,000, 3,000, 2,000 and 1,000 p.p.m. solutions.

Magnesium Chloride Cultures: In the magnesium chloride cultures a toxicity toward Lahaina was evident in 4 days' time in the 4,000, 3,000, and 2,000 p.p.m. cultures. As in the other series, during the early stages of the experiment, H 109 failed to show any disturbance other than stunted growth as compared to the checks. As shown in Figs. 5 and 5A, H 109 as compared to Lahaina made better root growth in the three most concentrated culture solutions. There was no leaf striping in this series.

Potassium Chloride Cultures: Some surprising results were obtained in the potassium chloride cultures, showing a striking toxicity of this salt toward H 109. In the Lahaina series there was little toxic action toward the roots, although the tops were greatly stunted, and in some cases dead in the two highest concentrations. This was the only chloride in which a good growth of secondary roots was obtained with the Lahaina. In the H 109 series the plants showed early toxic effects from the K Cl at these concentrations, and at the end of one month all plants were dead in the 4,000, 3,000, and 2,000 p.p.m. cultures, although there was fair root growth at 2,000 p.p.m. The comparative growth is shown in Figs. 6 and 6A.

Mixed Chloride Cultures: The results obtained in this series are significant and indicative of the different effects of high chloride concentrations in the field upon the growth of Lahaina and H 109. With the possible exception of the sodium chloride series the combined chlorides showed greater toxicity toward Lahaina than any chloride singly. This was especially true with the rapidity in which the plants succumbed to the highest concentrations. Four days after placing the shoots in the culture solutions toxicity was evident in all Lahaina plants. On the other hand, with H 109 this series was by far the healthiest set of plants in the entire experiment, with the possible exception of the potassium sulphate set. Little toxicity was evident even at 4,000 and 3,000 p.p.m. The poorest plants were obtained in the solutions containing 2,000 p.p.m. chloride. The most significant difference was in the top growth which, in the preceding series, it will be noted was most often affected (see Figs. 7 and 7A).

Magnesium Sulphate Series: Magnesium sulphate showed notably less toxicity toward Lahaina than the chloride. Injury appeared principally in the tops, which were badly stunted in growth by the high concentration of salt. Secondary root growth was fairly good in this series. On the other hand, this salt appeared to be more toxic toward H 109 than Lahaina. The secondary roots were markedly stunted as compared to the Lahaina roots. There was little or no chlorosis in this series as compared to the magnesium chloride. These cultures are shown in Figs. 8 and 8A.

Sodium Sulphate Series: Of the sulphates, sodium sulphate produced the greatest injury to the Lahaina. This was shown in an almost entire absence of roots in the 4,000 p.p.m. culture and the marked wilting of the tops in the entire series. At 1,000 p.p.m. there were good secondary roots. In the H 109 plants there was better root and top growth at 4,000 p.p.m., but in the rest of the series root development was more greatly retarded in the H 109. The color of the tops in spite of the notable stunted growth was practically normal. The comparative growth is shown in Figs. 9 and 9A.

Potassium Sulphate Cultures: Potassium sulphate in all the concentrations used in this series had little or no effect upon the development of the roots in either variety during the one month period of the experiment. Also, there was little or no effect on the top growth of the H 109, in striking contrast to the potassium chloride series. The Lahaina tops were slightly chlorotic and wilted, but not greatly stunted in growth. It is of interest to compare the growth of both varieties in the potassium sulphate and chloride series. These salts illustrate more clearly than the others the comparative toxicity of the sulphate and chloride radicals. The potassium sulphate series are shown in Figs. 10 and 10A.

While it is recognized that certain limitations must be placed on the interpretation of results obtained in water culture experiments when applying the results to field conditions, it is believed that in the comparative behavior of H 109 and Lahaina in the mixed chloride cultures there lies the cause of the difference in fertility of highly saline soils when cropped to these two varieties. That is to say, H 109 possesses a greater selective power than Lahaina, has the property to withstand greater concentrations of chlorides in its cell sap, or is more greatly favored by antagonism. This difference in selective power of plants and varieties, and

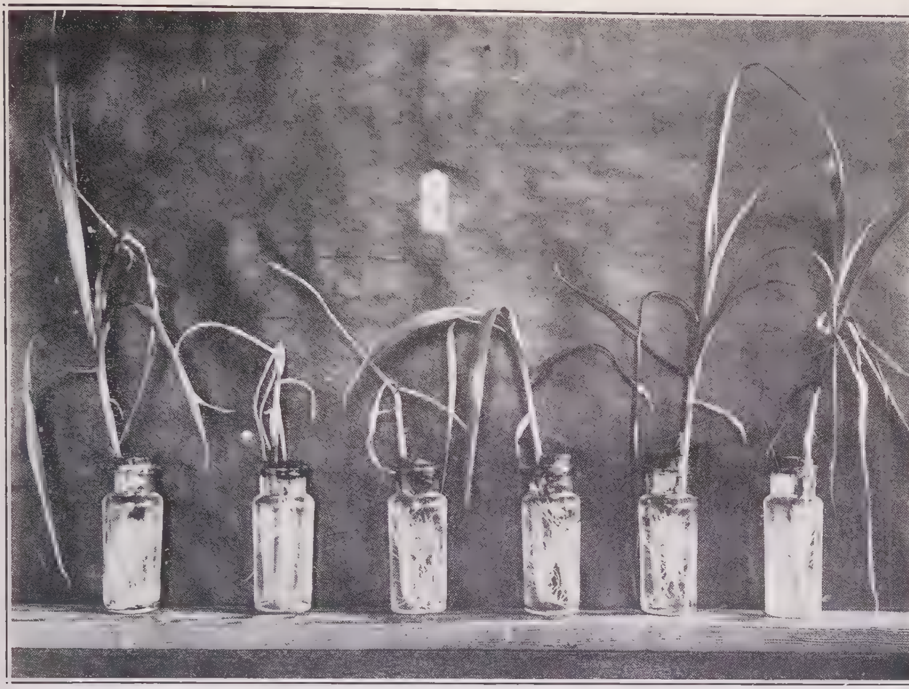

Fig. 3. Showing effect of sodium chloride on growth of Lahaina variety (1 month).

Left to right: 1. Control—nutrient solution. 2. Nutrient + sodium chloride (4,000 p.p.m. Cl). 3. Nutrient + sodium chloride (3,000 p.p.m. Cl). 4. Nutrient + sodium chloride (2,000 p.p.m. Cl). 5. Nutrient + sodium chloride (1,000 p.p.m. Cl). 6. Nutrient + sodium chloride (500 p.p.m. Cl).

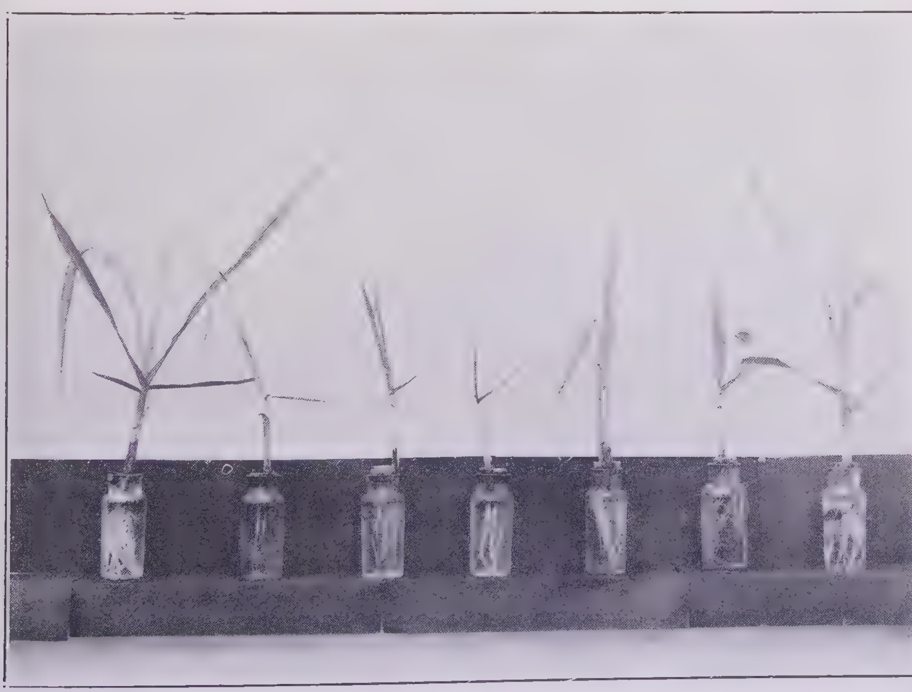

Fig. 3A. Showing effect of sodium chloride on growth of H 109 variety (1 month).

Left to right: 1. Control—nutrient only. 2. Nutrient + sodium chloride (4,000 p.p.m. Cl). 3. Nutrient + sodium chloride (3,000 p.p.m. Cl). 4. Nutrient + sodium chloride (2,000 p.p.m. Cl). 5. Nutrient + sodium chloride (1,000 p.p.m. Cl). 6. Nutrient + sodium chloride (500 p.p.m. Cl). 7. Control—nutrient only.

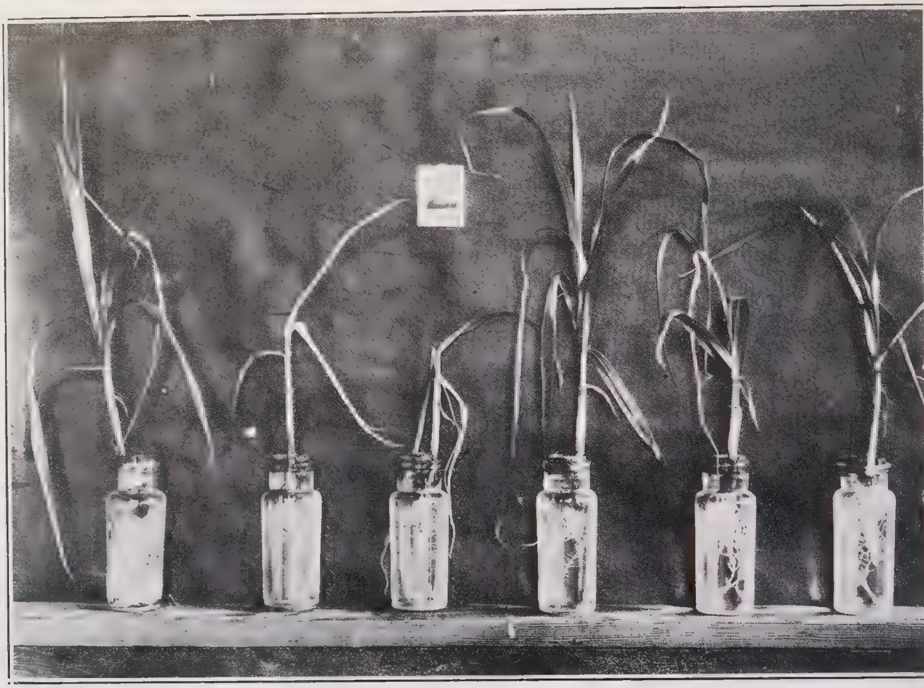

Fig. 4. Showing effect of calcium chloride on growth of Lahaina variety (1 month). Left to right: 1. Control—nutrient solution. 2. Nutrient + calcium chloride (4,000 p.p.m. Cl). 3. Nutrient + calcium chloride (3,000 p.p.m. Cl). 4. Nutrient + calcium chloride (2,000 p.p.m. Cl). 5. Nutrient + calcium chloride (1,000 p.p.m. Cl). 6. Nutrient + calcium chloride (500 p.p.m. Cl).

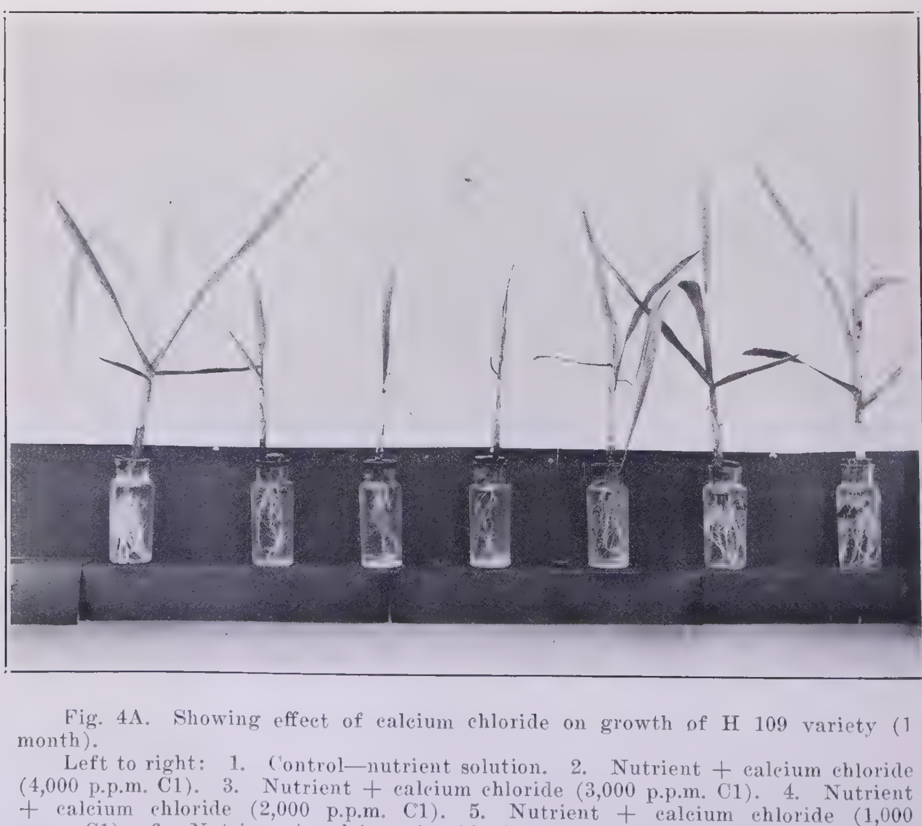

Fig. 4A. Showing effect of calcium chloride on growth of H 109 variety (1 month).

Left to right: 1. Control—nutrient solution. 2. Nutrient + calcium chloride (4,000 p.p.m. Cl). 3. Nutrient + calcium chloride (3,000 p.p.m. Cl). 4. Nutrient + calcium chloride (2,000 p.p.m. Cl). 5. Nutrient + calcium chloride (1,000 p.p.m. Cl). 6. Nutrient + calcium chloride (500 p.p.m. Cl). 7. Control—nutrient only.

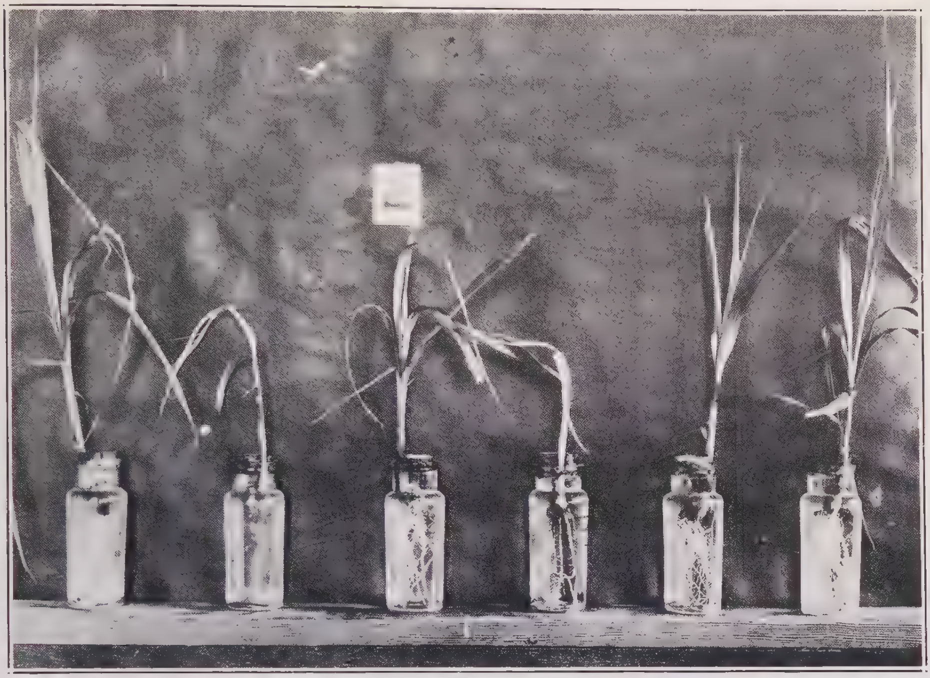

Fig. 5. Showing effect of magnesium chloride on growth of Lahaina variety (1 month).

Left to right: 1. Control—nutrient solution. 2. Nutrient + magnesium chloride (4,000 p.p.m. Cl). 3. Nutrient + magnesium chloride (3,000 p.p.m. Cl). 4. Nutrient + magnesium chloride (2,000 p.p.m. Cl). 5. Nutrient + magnesium chloride (1,000 p.p.m. Cl). 6. Nutrient + magnesium chloride (500 p.p.m. Cl).

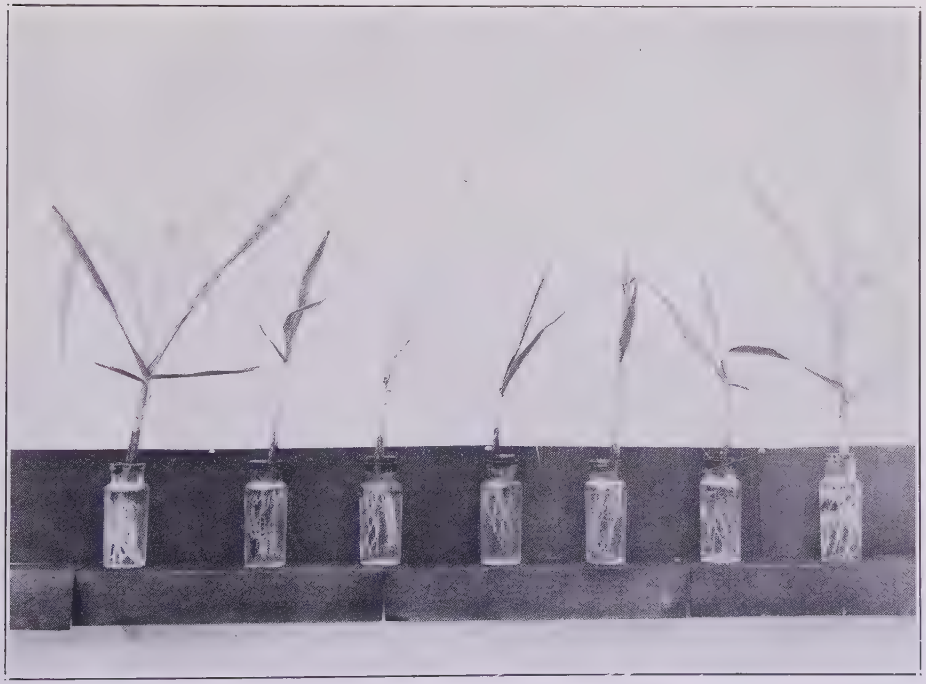

Fig. 5A. Showing effect of magnesium chloride on growth of H 109 variety (1 month).

Left to right: 1. Control—nutrient only. 2. Nutrient + magnesium chloride (4,000 p.p.m. Cl). 3. Nutrient + magnesium chloride (3,000 p.p.m. Cl). 4. Nutrient + magnesium chloride (2,000 p.p.m. Cl). 5. Nutrient + magnesium chloride (1,000 p.p.m. Cl). 6. Nutrient + magnesium chloride (500 p.p.m. Cl). 7. Control—nutrient only.

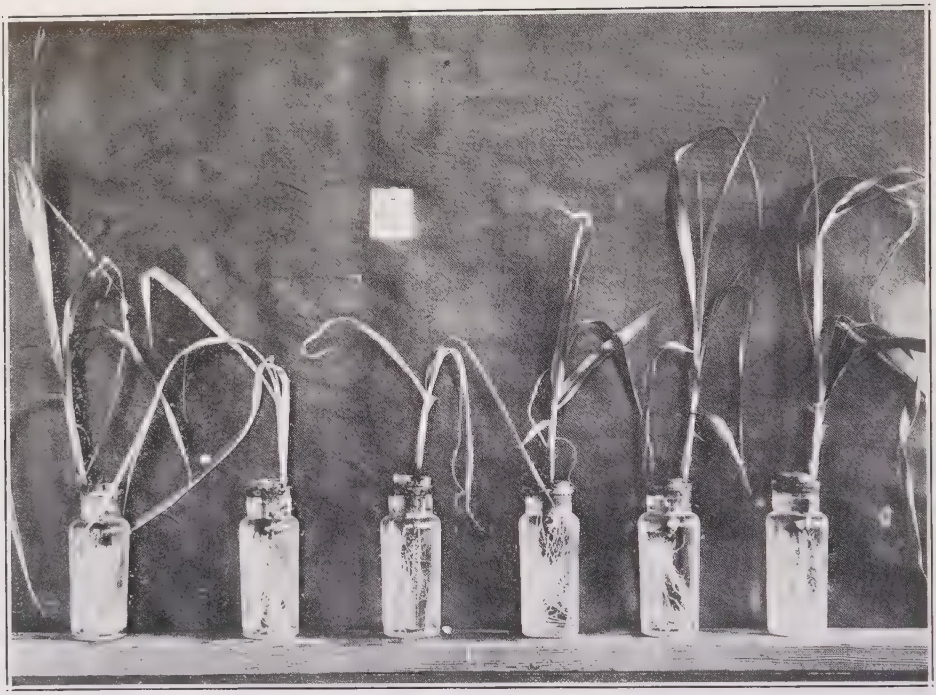

Fig. 6. Showing effect of potassium chloride on growth of Lahaina variety (1 month).

Left to right: 1. Control—nutrient solution. 2. Nutrient + potassium chloride (4,000 p.p.m. Cl). 3. Nutrient + potassium chloride (3,000 p.p.m. Cl). 4. Nutrient + potassium chloride (2,000 p.p.m. Cl). 5. Nutrient + potassium chloride (1,000 p.p.m. Cl). 6. Nutrient + potassium chloride (500 p.p.m. Cl).

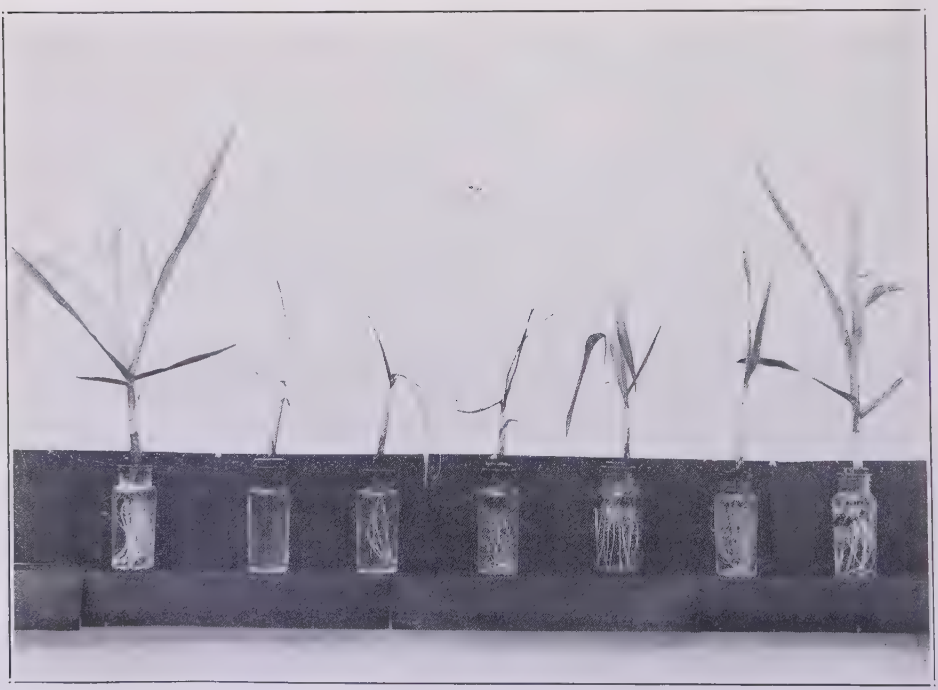

Fig. 6A. Showing effect of potassium chloride on growth of H 109 variety (1 month).

Left to right: 1. Control—nutrient solution. 2. Nutrient + potassium chloride (4,000 p.p.m. Cl). 3. Nutrient + potassium chloride (3,000 p.p.m. Cl). 4. Nutrient + potassium chloride (2,000 p.p.m. Cl). 5. Nutrient + potassium chloride (1,000 p.p.m. Cl). 6. Nutrient + potassium chloride (500 p.p.m. Cl). 7. Control—nutrient only.

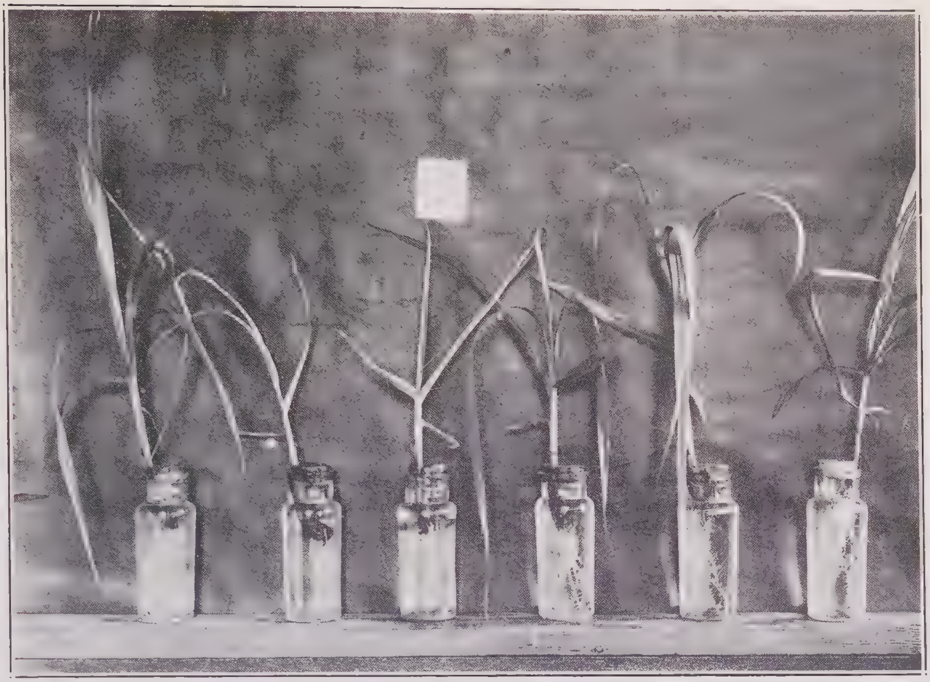

Fig. 7. Showing effect of mixed chlorides of sodium, calcium and magnesium on growth of Lahaina variety (1 month).

Left to right: 1. Control—nutrient only. 2. Nutrient + chlorides (4,000 p.p.m. Cl). 3. Nutrient + chlorides (3,000 p.p.m. Cl). 4. Nutrient + chlorides (2,000 p.p.m. Cl). 5. Nutrient + chlorides (1,000 p.p.m. Cl). 6. Nutrient + chlorides (500 p.p.m. Cl).

Fig. 7A. Showing effect of mixed chlorides of sodium, calcium and magnesium on growth of H 109 variety (1 month).

Left to right: 1. Control—nutrient only. 2. Nutrient + chlorides (4,000 p.p.m. Cl). 3. Nutrient + chlorides (3,000 p.p.m. Cl). 4. Nutrient + chlorides (2,000 p.p.m. Cl). 5. Nutrient + chlorides (1,000 p.p.m. Cl). 6. Nutrient + chlorides (500 p.p.m. Cl). 7. Control—nutrient only.

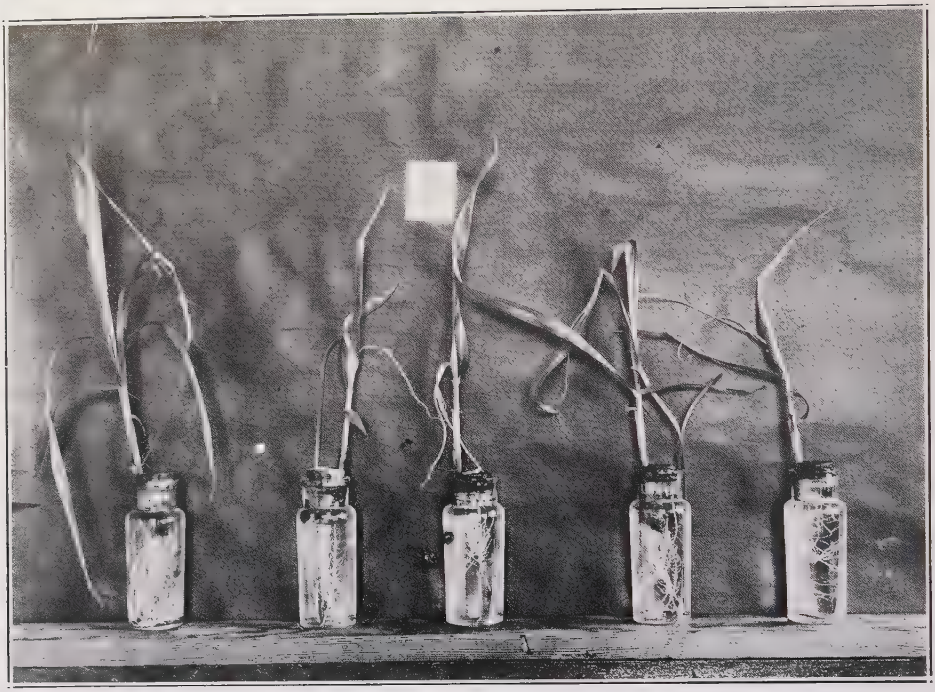

Fig. 8. Showing effect of magnesium sulphate on growth of Lahaina variety (1 month).

Left to right: 1. Control—nutrient solution. 2. Nutrient + magnesium sulphate (4,000 p.p.m. SO_4). 3. Nutrient + magnesium sulphate (3,000 p.p.m. SO_4). 4. Nutrient + magnesium sulphate (2,000 p.p.m. SO_4). 5. Nutrient + magnesium sulphate (1,000 p.p.m. SO_4).

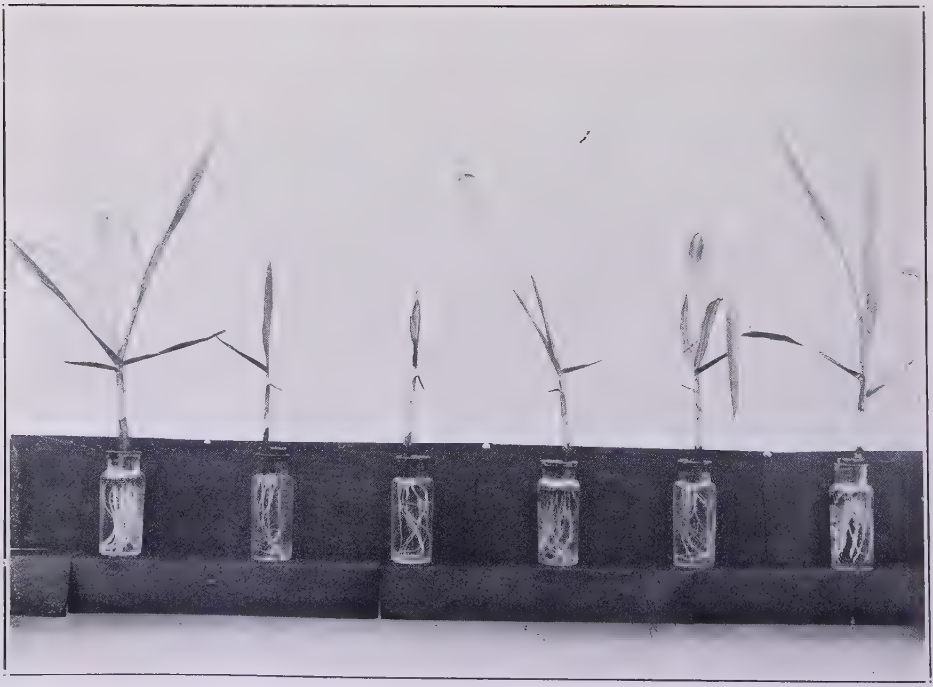

Fig. 8A. Showing effect of magnesium sulphate on growth of H 109 variety (1 month).

Left to right: 1. Control—nutrient only. 2. Nutrient + magnesium sulphate (4,000 p.p.m. SO_4). 3. Nutrient + magnesium sulphate (3,000 p.p.m. SO_4). 4. Nutrient + magnesium sulphate (2,000 p.p.m. SO_4). 5. Nutrient + magnesium sulphate (1,000 p.p.m. SO_4). 6. Control—nutrient only.

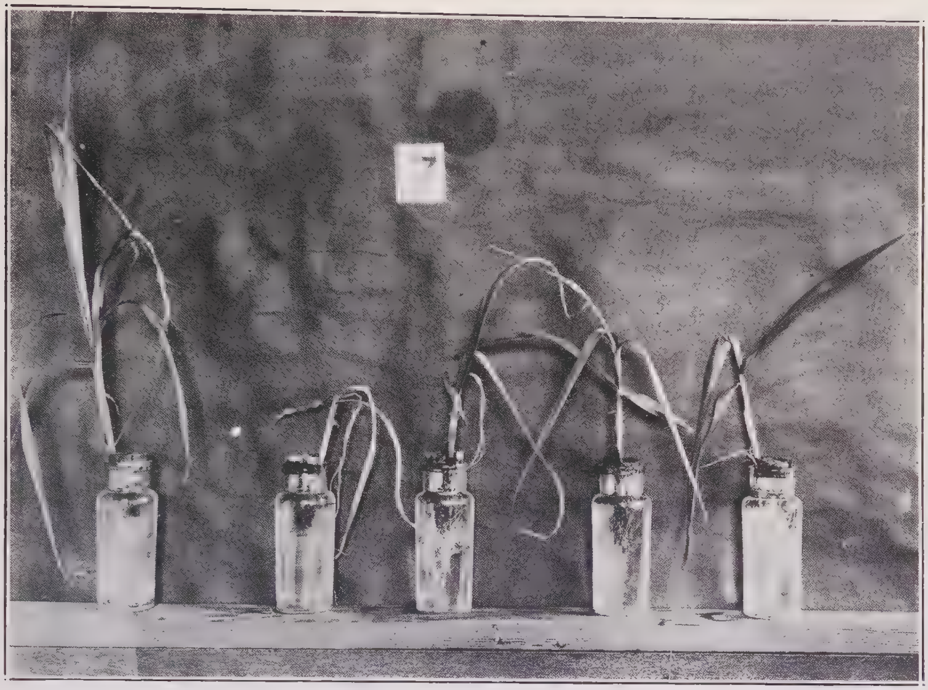

Fig. 9. Showing effect of sodium sulphate on growth of Lahaina variety (1 month). Left to right: 1. Control—nutrient solution. 2. Nutrient + sodium sulphate (4,000 p.p.m. SO_4). 3. Nutrient + sodium sulphate (3,000 p.p.m. SO_4). 4. Nutrient + sodium sulphate (2,000 p.p.m. SO_4). 5. Nutrient + sodium sulphate (1,000 p.p.m. SO_4).

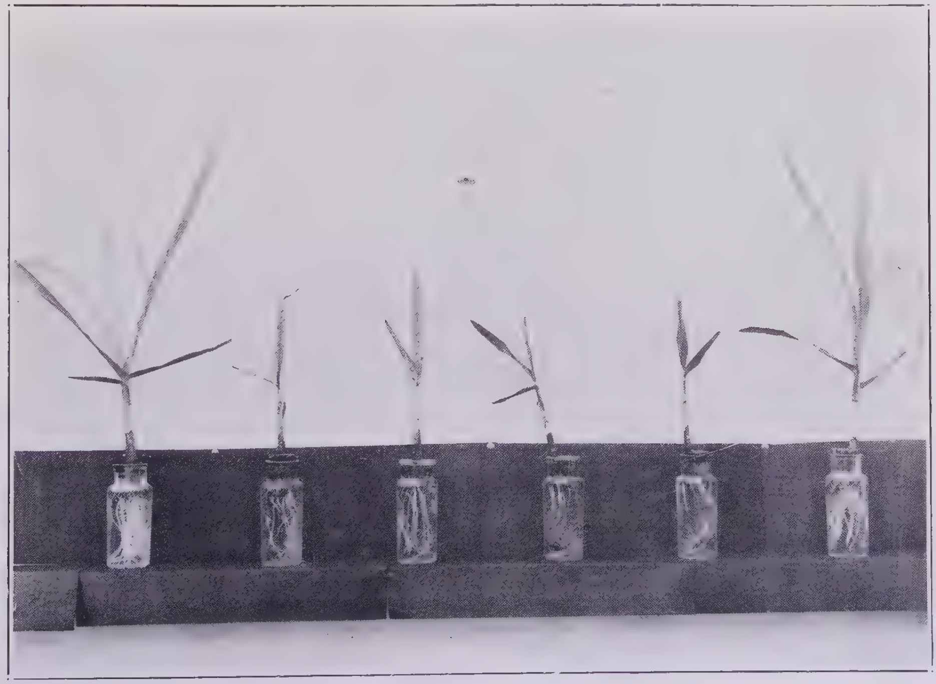

Fig. 9A. Showing effect of sodium sulphate on growth of H 109 variety (1 month). Left to right: 1. Control—nutrient only. 2. Nutrient + sodium sulphate (4,000 p.p.m. SO_4). 3. Nutrient + sodium sulphate (3,000 p.p.m. SO_4). 4. Nutrient + sodium sulphate (2,000 p.p.m. SO_4). 5. Nutrient + sodium sulphate (1,000 p.p.m. SO_4). 6. Control—nutrient only.

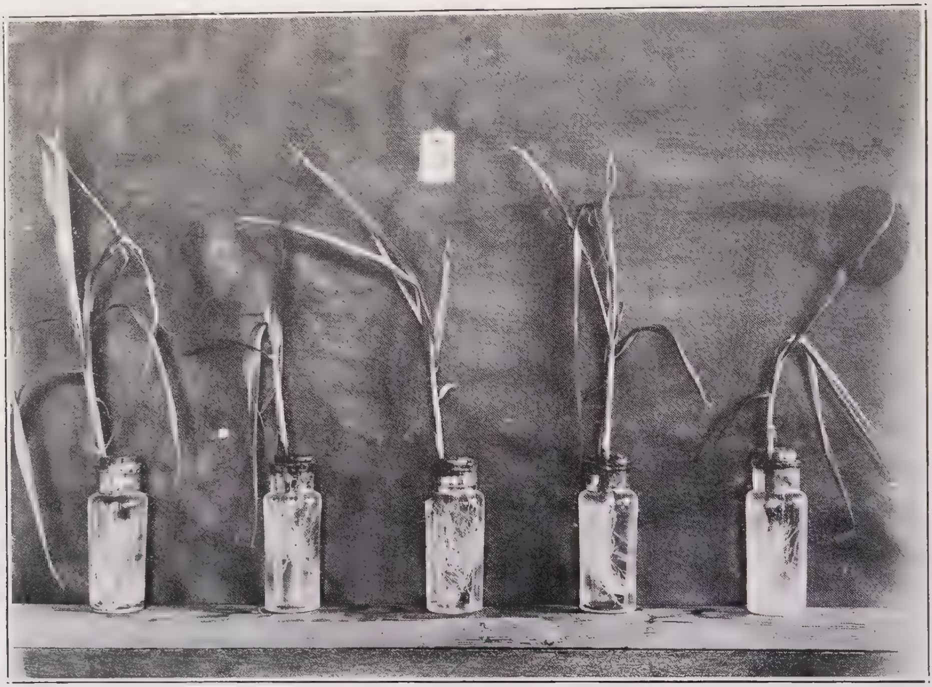

Fig. 10. Showing effect of potassium sulphate on growth of Lahaina variety (1 month).

Left to right: 1. Control—nutrient solution. 2. Nutrient + potassium sulphate (4,000 p.p.m. SO_4). 3. Nutrient + potassium sulphate (3,000 p.p.m. SO_4). 4. Nutrient + potassium sulphate (2,000 p.p.m. SO_4). 5. Nutrient + potassium sulphate (1,000 p.p.m. SO_4).

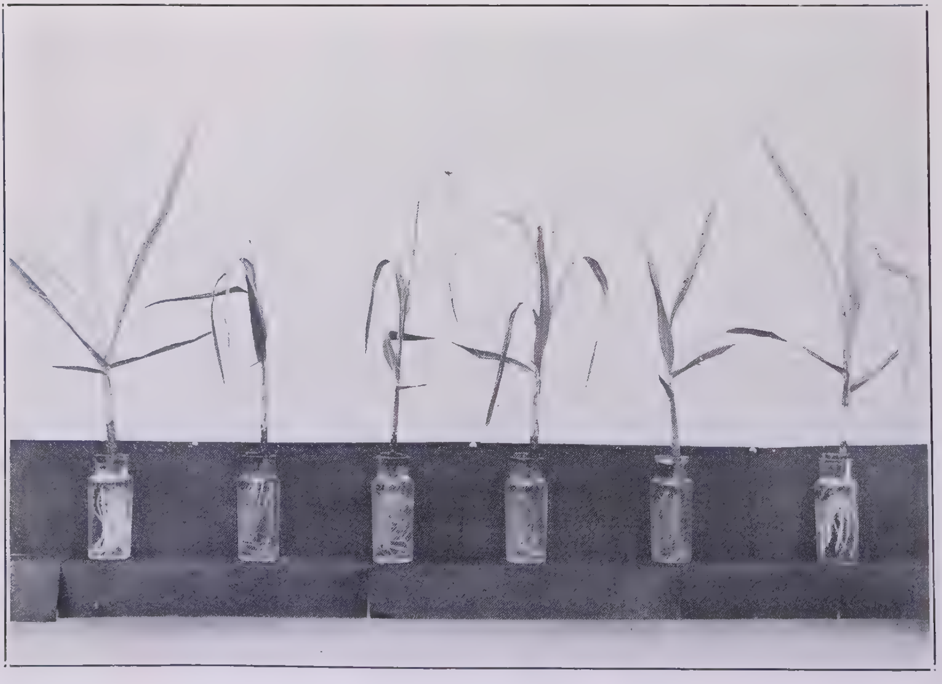

Fig. 10A. Showing effect of potassium sulphate on growth of H 109 variety (1 month).

Left to right: 1. Control—nutrient only. 2. Nutrient + potassium sulphate (4,000 p.p.m. SO_4). 3. Nutrient + potassium sulphate (3,000 p.p.m. SO_4). 4. Nutrient + potassium sulphate (2,000 p.p.m. SO_4). 5. Nutrient + potassium sulphate (1,000 p.p.m. SO_4). 6. Control—nutrient only.

also the antagonism between salts or their acid and basic radicals in entering the roots, has often been noted in plant physiology.

The physiological effects of chlorides have been extensively studied by Osterhout (12), who has shown that ions penetrate living protoplasm and that many ions which penetrate quite rapidly in pure solutions may be hindered or prevented from going in by the addition of small amounts of other salts. For example, calcium chloride, strontium chloride and barium chloride are able to hinder very greatly the entrance of the ions of sodium chloride. The mechanism is not fully understood, but he has noted visible changes in the plasma membrane which are entirely different from those produced by such salts as sodium chloride. He suggests that there is good evidence to show that sodium chloride does not enter the cell alone but is accompanied by calcium chloride. He says that it is possible that these salts may wholly prevent each other from penetrating nuclear membranes, which is of importance in this connection. The antagonistic action of salts is largely or entirely due to the fact that they hinder or prevent one another from entering the protoplasm.

The antagonism between salts has also been studied by Reed and Haas (14) on citrus and walnut seedlings. Nutrients containing toxic amounts of sodium chloride were made less toxic on addition of calcium chloride in spite of the fact that the concentration of the chlorine was increased thereby. They found that orange trees absorb chlorine readily and their growth is characteristically affected by amounts which would be harmless in the case of certain other ions. The effect of sodium chloride on trees growing in soils under control conditions show a restricted growth of roots and shoots, the premature abscission of leaves agreeing with the analyses, which show an increased amount of chlorine absorbed.

Miyake (11), working with rice, also found a marked antagonism in saline solutions and a notable toxicity from chlorides.

The principal function of the root system is absorption of water and inorganic salts. Water enters the plant through the root hairs and passes out principally through the stomata in the surface of the leaves. Thus there is an unbroken stream of water passing through the plant. A number of factors may restrict the rate of flow, and too rapid transpiration or too slow absorption will seriously retard normal development. Among the factors affecting the intake of water by the roots are included the composition and concentration of the soil solution. This process of water intake tends to go on as long as the total concentration of the cell sap of the root hair cells is greater than that of the soil solution surrounding the root hairs. The greater the difference in concentration between the cell sap and the soil solution the more rapid the water movement. If the concentration of the soil solution approaches that of the cell sap the rate of absorption slows down. The roots of plants growing in highly saline soils are often surrounded by a soil solution of sufficiently high concentration to retard absorption. In such cases there may be present plenty of water in the soil, but the plant can secure it only with great difficulty on account of the high concentration of the soil solution. This is often termed a physiological drought and was often observed on Lahaina plants affected by the so-called Lahaina disease on irrigated fields. In fact this was one of the principal characteristics of the affected stools.

In one case we have a physiological inability to absorb water, due to a high salt concentration, while in a physical drought we have an actual moisture deficiency.

The composition of such saline accumulations is also closely involved in the functional processes of absorption. The rate of entrance of a given salt is determined chiefly by its concentration in the cell sap. If the concentration of a given salt in the cell sap is less than the concentration of that same salt in the soil solution then that salt tends to diffuse inwardly. It is thus evident that, depending upon the varietal powers of selection possessed by plant varieties, excessive quantities of undesirable or toxic salts may gain entrance by diffusion into the tissues. Through differences in the character of the cytoplasm membrane many plants possess selective properties. There may be a rapid absorption of some salt, for example, potassium sulphate, while another salt at that time may be entering the root hairs in comparatively much lesser amounts. The quantities of the many salts present in the soil solution required or assimilated by the plant are also to be considered. Whereas salts pass from the soil solution into the roots, with the exception of water and carbon dioxide, these same salts are unable to pass from the roots to the soil solution. It is evident from this that once within the plant non-assimilable salts will often reach sufficient concentration to seriously retard the normal plant processes.

On the whole, the water cultures did not show sufficient differences in the action of the single salts to account for the differences in the growth of Lahaina and H 109 on the highly saline soils. The toxicity toward H 109 was more sluggish than with the Lahaina, but once the plant showed distress it failed rapidly from this point. The difference in growth of these two varieties in fields where saline accumulations have taken place is unquestionably a property of the combined chlorides. In other words, in the presence of the several salts H 109 is able to adapt itself through the possession of a property lacking in the functional processes of the Lahaina variety.

It is of interest in this connection to present the observations of the several plantation managers and the Experiment Station men who have given attention to the Lahaina failure on the irrigated plantations. These are taken from the discussions at the meetings of the H. S. P. A., and from the reports on file at the Experiment Station. Attention is especially called to the many references to and the observations on the improved growth of Lahaina which followed excessive irrigation and heavy rainfalls, which is direct proof of the relation of soluble materials in the soil to the poor growth of Lahaina in these cases.

The first reports on file are those of Lewton-Brain, beginning in October, 1905, in which, while he confined his investigations to the fungi present in the rotted roots, he stated that "a few weeks later with constant large irrigation the cane apparently entirely recovers." Lyon, continuing this work, suggested in 1908 from his observations at Ewa that the "appearance of the Lahaina was not that of an infectious disease but rather of poor drainage." Larsen in a report of February, 1909, in describing the condition of the diseased cane, mentions the dry leaf tips and greater injury along the irrigation ditches, especially those constantly full of water. About this same time Lyon describes the diseased cane as "of that suffering for water."

In the annual report for 1913 Peck mentions having found high alkalinity in some of the soils about diseased stools. This point came up for extensive discussion at the annual meeting of the Association for the same year. The following extracts from this discussion are of interest. Peck had installed extensive experiments in a diseased area at Waipio: "Unfortunately, for our experiments, the weather conditions have been such that all the cane has come along beautifully in the last six months. Cane which was given up has, we have discovered, grown to normal cane." During this discussion James Gibb, referring to this recovery, made the following significant statement: "In May or June we had a heavy rain. We had *six inches* of rain in *24 hours,* and later there was a lighter rain amounting to about *four inches.* I do not know, but I offer it as a possible explanation of how it came about, and I would like to ask if that was not the experience at the Station. I just speak of that unusual rainfall which might have brought about that condition. I know our cane came up very rapidly." Gibb's observations were fully confirmed during this discussion by Agee.

During this discussion Mr. Renton stated: "I think it is a question of too wet or too dry and something in the nature of the soil." In the wet soil near the ditches there would be high concentration of salt from the continuous supply, while in the dry soil concentration would result from evaporation.

At the 1914 annual meeting of the Association the Lahaina failure again came up for discussion.

H. P. Agee: There seems to be a serious thing in connection with this trouble; while the other varieties are so much more resistant to the trouble than the Lahaina, yet there are instances where the seedlings succumb to the same condition, but in a very much less degree than the Lahaina variety. Whether it is a question of *brackish water,* which fresh water will overcome, we cannot say.

J. F. C. Hagens: Is it not only on the lands irrigated with artesian water?

H. P. Agee: The symptoms are not definite enough to say that. It is true that the worst trouble is where artesian water is being applied. . . .

In 1915, Speare made an extensive survey of the affected fields at Honolulu Plantation and Oahu Sugar Company. The following observations are significant:

Oahu Sugar Company: Both mauka and makai fields are affected. Almost invariably the disease is more intense and first appears in connection with the watercourses, level ditches and straight ditches. If in connection with a level ditch, the cane appears in bad condition below it and good above it. It will thus run along the makai side of the ditch for some distance and then after a time appear on the mauka side, after which it spreads more rapidly. The cause is *augmented by pump water.*

Honolulu Plantation: The disease was worst in the high coral fields around Puuloa. "One striking exception is apparent in Field 17 where an area one watercourse in width is in good cane though surrounded by diseased cane. *This small area receives night water from the mill in distinction from the neighboring areas."*

Burgess, like Peck, noted excessive alkalinity in some soils about infected stools and made a very intensive study of the toxicity of "Black" alkali toward cane. His investigations very strongly indicated that this form of alkali may, in many

of the irrigated fields, be associated with their low fertility. It is of interest to note in his experiments that there was less disease during the years of heaviest rainfall and that the disease occurred mostly in sections where the rainfall was less than 20 inches per year.

Conclusions

1. On the irrigated plantations there is shown to be a greater accumulation of saline material in many fields where Lahaina failed than where this variety is still making good growth. It is by no means suggested or contended that saline accumulation was the only cause of Lahaina failure on all the fields of the irrigated plantations, but rather to show that in many fields it has reached a toxic concentration for this variety and was instrumental or a contributing agent in the failure of this variety in many cases.

2. The growth of Lahaina is greatly increased in these soils by heavy irrigation. This is shown by the pot experiments and by the several references to observations on the effect of heavy rainfalls on the increased fertility of such fields during the period that "Lahaina disease" was at its worst.

3. It was shown by water cultures, using high concentrations of single salts, that there was a marked toxicity to both the Lahaina and H 109 under the conditions of the experiment. While these salts singly were in most cases slightly more toxic toward Lahaina, the difference was not sufficient to account for the wide differences in the growth of these two varieties in the fields where large amounts of salt have accumulated.

4. By growing Lahaina and H 109 in cultures to which instead of adding the salts singly they were added together in approximately the same ratio in which they are found in the field, there was shown a far greater toxicity toward Lahaina. It is believed that this experiment shows quite conclusively that the unlike growth of these two varieties on the highly saline soils is due either to a basic antagonism or a greater selective power of resistance in the H 109 variety.

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The Prevalence of Nut Grass on Island Soils as Influenced by Soil Reaction

By W. T. McGeorge

During the course of our investigations on the fertility of the acid plantation soils, the writer made the observation that nut grass (*Cyperus rotundus*) was notably absent or made very poor growth on such types. The question arose, naturally, as to the underlying causes of this characteristic of nut grass and its possibility as a control measure on a field scale; that is, what is the constituent of acid soils which is toxic toward nut grass, and can it be produced in the field by the application of chemicals?

As has been pointed out in previous articles in the *Record,* Island soils contain soluble aluminum which is known to be toxic toward many plants. Experiments were therefore planned to determine whether the toxicity toward nut grass was the acidity itself, the salts of aluminum, or some hitherto unidentified agent. The

experimental procedure involved growing this plant in water cultures to which sulphuric acid and aluminum salts had been added.

Water Cultures

Nutrient Solution: The following nutrient solution was used in the water cultures:

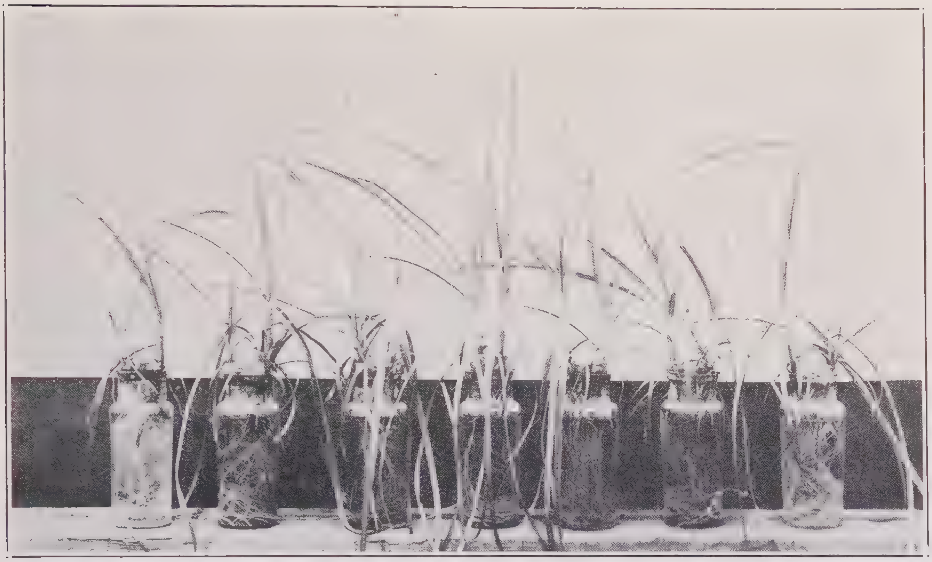
.2 N Calcium nitrate	15 cc. per litre
.1 N Ammonium nitrate	10 " " "
.1 N Potassium chloride	8 " " "
.2 N Magnesium sulphate	8 " " "
8.3 gms. Calcium phosphate per litre	5 " " "
Ferric citrate	trace

Using the above nutrient solution as a basis, two sets of cultures were prepared. To one set was added increasing amounts of aluminum chloride. To the second set sulphuric acid was added in amounts sufficient to produce the same range of acidity or hydrogen ion concentration as obtained in the aluminum cultures. The plan was as follows:

1.	Control-nutrient solution only	pH 6.8
2.	Nutrient 4 cc. .2 N aluminum chloride	" 4.3
3.	" 6 cc. " " "	" 4.0
4.	" 8 cc. " " "	" 4.0
5.	" 10 cc. " " "	" 4.0
6.	" 25 cc. " " "	" 4.0
7.	" sulphuric acid to give	" 6.4
8.	" " " " "	" 5.6
9.	" " " " "	" 5.2
10.	" " " " "	" 4.6
11.	" " " " "	" 4.2
12.	" " " " "	" 3.9

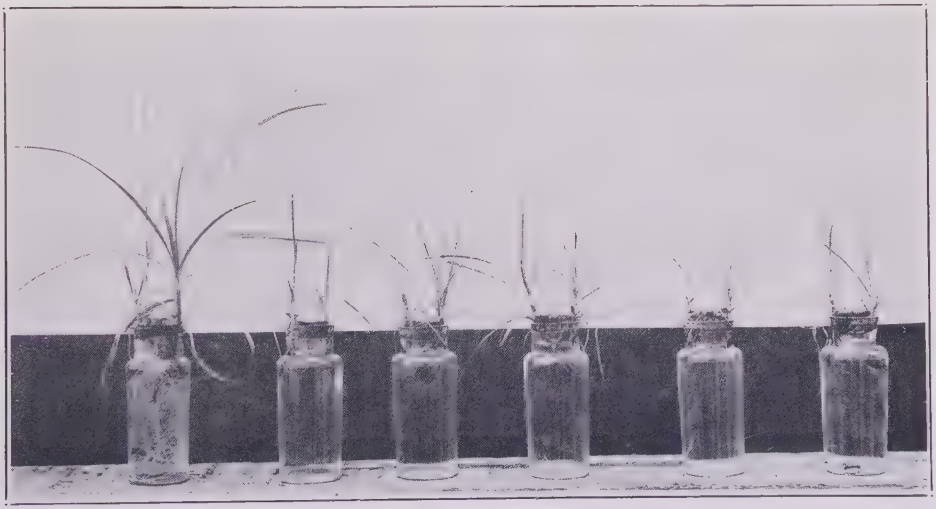
Healthy young plants about 4 inches in height were obtained from the Experiment Station grounds where nut grass grows in profusion for use in these cultures. One-half of the plants were taken with the bulb or "nut" attached and one-half without. The plants were suspended in 250 cc. wide mouth bottles containing the above solutions, by means of a cork with slots extending in toward the center, as shown in the illustrations.

The plants were started in the cultures on September 12, and were photographed, as shown in Fig. 1, on October 13. These cultures show quite conclusively that the toxic constituent of acid soils retarding the growth of nut grass is not the acidity of the soil or hydrogen ion concentration *per se*. As a matter of fact the growth of nut grass was greatly stimulated by the acid. On the other hand, the plants in the solutions to which aluminum chloride was added while they remained alive in all cases, there was absolutely no root growth and no further growth of tops over the original height. It seems fair to interpret from this that aluminum is the growth retarding constituent of acid Island soils so far as nut grass is concerned. On October 18, the plants in this experiment were



Nut grass in water cultures + sulphuric acid.

Left to right: 1. Control—nutrient solution. 2. Nutrient solution + sulphuric acid to pH 6.4. 3. Nutrient solution + sulphuric acid to pH 5.6. 4. Nutrient solution + sulphuric acid to pH 5.2. 5. Nutrient solution + sulphuric acid to pH 4.6. 6. Nutrient solution + sulphuric acid to pH 4.2. 7. Nutrient solution + sulphuric acid to pH 3.8.



Nut grass in water cultures + aluminum chloride.

Left to right: 1. Control—nutrient solution. 2. Nutrient solution + 4 cc. .2N aluminum chloride pH 4.3. 3. Nutrient solution + 6 cc. .2N aluminum chloride pH 4.0. 4. Nutrient solution + 8 cc. .2N aluminum chloride pH 4.0. 5. Nutrient solution +10 cc. .2N aluminum chloride pH 4.0. 6. Nutrient solution + 25 cc. .2N aluminum chloride pH 4.0.

Fig. 1

reversed, that is, the large plants from the acid cultures were transferred to the aluminum and vice versa. The root tips of the plants from the former in a few days after changing to the aluminum chloride nutrient solutions became brown and discolored and there was a notable chlorosis (yellow) and premature dying of the leaves.

The "dormant" plants from the aluminum cultures on changing to the acid nutrient soon sent out roots and started to grow and, while stunted, as compared to the check plants, made a good growth.

Pot Experiments

In view of the above, a series of soil treatments was planned involving the application of fertilizer compounds of a residual acidity. Ammonium sulphate, sulphur and aluminum chloride were chosen as three such materials. Pots containing 10 lbs. soil were used and were filled with soil from the Makiki Plots. This soil is alkaline in reaction and very highly buffered, that is to say, it resists strongly the effect of acid fertilizers in its reaction. The following table gives in detail the plan of the experiment:

ALUMINUM CHLORIDE SERIES

1.	Soil untreated							
2.	17	grams	Aluminum	chloride	added	(approx.	6	t.p.a.)
3.	28	"	"	"	"	"	9	"
4.	39	"	"	"	"	"	13	"
5.	55	"	"	"	"	"	18	"

SULPHUR SERIES

	Soil untreated						
2.	25.5	gms.	Sulphur	added	(approx.	8	t.p.a.)
3.	50	"	"	"	"	16	"
4.	100	"	"	"	"	32	"
5.	200	"	"	"	"	64	"
6.	300	"	"	"	"	128	"

AMMONIUM SULPHATE SERIES

1.	Soil untreated							
2.	12.5	gms.	Ammonium	sulphate	added	(approx.	4	t.p.a.)
3.	25	"	"	"	"	"	8	"
4.	50	"	"	"	"	"	16	"
5.	100	"	"	"	"	"	32	"
6.	200	"	"	"	"	"	64	"
7.	300	"	"	"	"	"	128	"

The above treatments were made on November 16, and the pots watered daily in order to germinate the nut grass nodules transferred to the pots with the soil and to allow time for the action of the chemicals before making the test. On February 5, the plants were removed from the pots and samples of soil were taken from each in order to determine the change in reaction produced by the chemicals. The pots were then immediately replanted with also a series of Ber-

muda grass merely for comparative purposes. The soil reactions are given in the following table:

TABLE 1

Pot No.	Aluminum Chloride	Sulphur	Ammonium Sulphate
1	8.01	8.01	8.01
2	7.67	5.13	7.84
3	7.33	4.71	7.42
4	7.33	4.63	6.74
5	7.08	4.46	5.81
6	....	4.46	4.97
7	....	....	4.38

This data shows the great resistance in this type of soil to acid fertilizers in that the aluminum chloride up to 18 tons per acre had little effect on the reaction. The same may be said of ammonium sulphate, where in excess of 32 tons per acre was required to give a toxic acidity. Sulphur showed the greatest residual acidity, the lowest application, namely, 8 tons per acre, producing a reaction of pH 5.13.

The plants were photographed April 27, and their condition at that time is shown in Fig. 2.

Aluminum Chloride: There being no production of acidity from the application of aluminum chloride, no toxicity was shown. This is in line with our investigation of aluminum toxicity in that a certain degree of acidity must be present in the soil to allow the solubility of the aluminum in the soil solution. As previously stated, this soil is very highly buffered and capable of throwing large quantities of aluminum out of solution into ineffective combinations.

Sulphur: This material was much more effective. A marked increase in acidity was obtained and likewise on increasing the acidity toxicity toward nut grass resulted. At the time the pots were photographed the plants in the last three were dead. Later on the other two pots became badly discolored also and there was little sign of life in the tops.

Ammonium Sulphate: In Table 1 it will be seen that the last two treatments produced a sufficient acidity to be toxic, yet no toxicity was shown at the time the plants were photographed. However, one month later the plants in the two pots receiving the highest applications were yellow and showed no signs of life.

This little experiment shows that in such a soil type as this any practical control of nut grass through soil reaction is out of the question unless over an extended period of applying ammonium sulphate or sulphur. In such highly buffered soils too large applications of chemicals would be required.

In view of the fact that this soil type is rarely found on plantations this experiment was repeated using a red clay, a very widely distributed type and one which is low in phosphates and other buffer agents. The plan of this experiment was similar to that with the Makiki soils in that 10 lbs. soil were used. On the other hand, knowing the different properties of this type smaller applications of chemicals were made. The following is the plan of this experiment:

Left to right: 1. Control—no treatment. 2. 10 lbs. soil + 17 grams aluminum sulphate. 3. 10 lbs. soil + 28 grams aluminum sulphate. 4. 10 lbs. soil + 39 grams aluminum sulphate. 5. 10 lbs. soil + 55 grams aluminum sulphate.

Left to right: 1. Control—no treatment. 2. 10 lbs. soil + 25 grams sulphur. 3. 10 lbs. soil + 50 grams sulphur. 4. 10 lbs. soil + 100 grams sulphur. 5. 10 lbs. soil + 200 grams sulphur. 6. 10 lbs. soil + 300 grams sulphur.

Left to right: 1. Control—no treatment. 2. 10 lbs. soil + 12.5 grams ammonium sulphate. 3. 10 lbs. soil + 25 grams ammonium sulphate. 4. 10 lbs. soil + 50 grams ammonium sulphate. 5. 10 lbs. soil + 100 grams ammonium sulphate. 6. 10 lbs. soil + 200 grams ammonium sulphate. 7. 10 lbs. soil + 300 grams ammonium sulphate.

Fig. 2

Nut grass top row—Bermuda grass bottom row. Makiki soil.

ALUMINUM CHLORIDE

1. Untreated soil
2. 15 grams aluminum chloride per pot (approx. 3.3 t.p.a.)
3. 25 " " " " " " 5.5 "
4. 35 " " " " " " 7.7 "

SULPHUR

1. Untreated soil
2. 5 grams sulphur per pot (approx. 1.1 t.p.a.)
3. 10 " " " " " 2.2 "
4. 20 " " " " " 4.4 "
5. 40 " " " " " 8.8 "
6. 60 " " " " " 13.2 "

AMMONIUM SULPHATE

Untreated soil
2. 5 grams ammonium sulphate per pot (approx. 1.1 t.p.a.)
3. 10 " " " " " " 2.2 "
4. 20 " " " " " " 4.4 "
5. 40 " " " " " " 8.8 "
6. 60 " " " " " " 13.2 "

The chemicals were applied to the soil on April 3, and nut grass planted April 15. The plants were photographed on May 29.

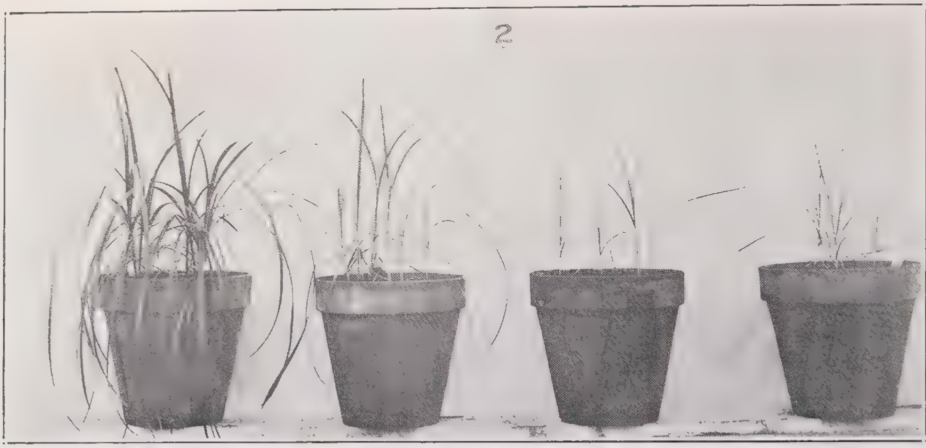
A sample of soil was taken from each pot for a determination of the soil reaction. The results are given in the following table:

Pot No.	Sulphur	Ammonium Sulphate	Aluminum Chloride
1	7.42	7.42	7.42
2	5.98	6.83	6.06
3	5.90	6.91	5.81
4	5.30	6.83	5.30
5	4.97	6.57	....
6	4.88	6.74	....

The soil in each pot was then well mixed, returned to the pots and replanted to nut grass on June 1. This set of plants was continued until July 29, when the plants were photographed and the reaction of the soil again determined. The reactions are given in the following table:

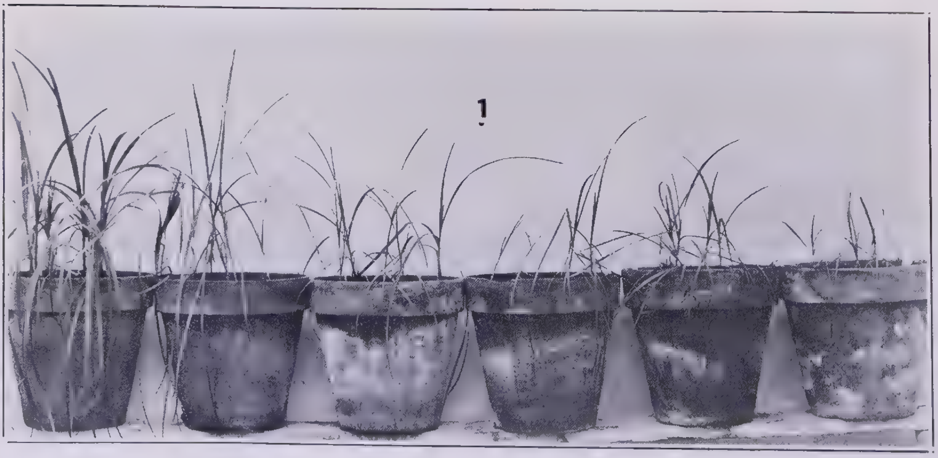
Pot No.	Sulphur	Ammonium Sulphate	Aluminum Chloride
1	7.67	7.67	7.67
2	5.90	7.92	6.15
3	5.81	7.50	6.74
4	4.80	7.33	5.80
5	3.71	7.00	....
6	3.28	7.00	....

The condition of the plants in the first planting is shown in Fig. 3, while only the sulphur series of the second planting is shown in Fig. 4.



Left to right: 1. Control—no treatment. 2. 10 lbs. soil + 15 grams aluminum chloride. 3. 10 lbs. soil + 25 grams aluminum chloride. 4. 10 lbs. soil + 35 grams aluminum chloride.

Left to right: 1. Control—no treatment. 2. 10 lbs. soil + 5 grams sulphur. 3. 10 lbs. soil + 10 grams sulphur. 4. 10 lbs. soil + 20 grams sulphur. 5. 10 lbs. soil + 40 grams sulphur. 6. 10 lbs. soil + 60 grams sulphur.



Left to right: 1. Control—no treatment. 2. 10 lbs. soil + 5 grams ammonium sulphate. 3. 10 lbs. soil + 10 grams ammonium sulphate. 4. 10 lbs. soil + 20 grams ammonium sulphate. 5. 10 lbs. soil + 40 grams ammonium sulphate. 6. 10 lbs. soil + 60 grams ammonium sulphate.

Fig. 3
Nut grass—Red clay soil.

Fig. 4. Nut grass—red clay soil—second planting.
Left to right: 1. Control—no treatment. 2. 10 lbs. soil + 5 grams sulphur. 3. 10 lbs. soil + 10 grams sulphur. 4. 10 lbs. soil + 20 grams sulphur. 5. 10 lbs. soil + 40 grams sulphur. 6. 10 lbs. soil + 60 grams sulphur.

Sulphur: These pot experiments on the red clay type indicate that in the use of sulphur may lie a method for the control of nut grass. The first planting, as shown in Fig. 4, was made at the time the sulphur was applied, and even up to the completion of the experiment much of the sulphur was still undecomposed. Toxicity was shown in pot No. 4 of reaction pH 5.3 (approximately 4 tons sulphur per acre). It is probable that later toxicity would develop in pot No. 3 (2 tons per acre), as the acidity was still increasing at the end of the experiment and was just at the toxic point.

Ammonium Sulphate: The plants in the first set were slightly stunted in growth, probably due to the heavy applications of salt, as there was no great increase in acidity at the end of the first planting and still less at the end of the second planting. It is probable that the continued use of ammonium sulphate over a period of years would gradually increase the soil acidity sufficient to kill out the nut grass.

Aluminum Chloride: In the first planting there was some toxicity shown before the aluminum chloride had been fixed by the soil. In the second planting it was shown only in the heaviest application at pH 5.80.

The relation between soil reaction and plant distribution, such as we have observed with nut grass, is by no means a new subject. Wherry (1) has shown the distribution of a species may be limited in a very definite way by soil reaction. He has confined his studies mostly to the distribution of natural flora, but his observations cover quite extensive investigations. Similar studies have been conducted in England by Atkins (2) in which also a definite relationship is shown. Wherry does not contend that reaction is the only factor of importance or that the acid acts directly on the plant. As he states, some plants may require for themselves or for symbiotic organism a soil of definite reaction; others may be affected by some physical or chemical property of the soil which accompanies such reaction; and still other plants may be driven into soils of a certain degree of acidity by more vigorous species which monopolize neighboring soils of greater or less acidities.

Some practical applications of this property of plants are of interest. Gillespie and Hurst (3) have shown a difference in the adaptation of soil types to potato culture. On a soil of pH 5.2 potatoes grew free from scab. At pH 5.93 they were badly attacked by this disease. In this case we have a difference in biological characteristics with reaction range or an indirect effect of soil reaction on plant growth of great importance, however, in potato culture. To grow potatoes free from scab it is only necessary to control the soil reaction by fertilization.

Another fungus disease, "finger-and-toe," develops to a harmful extent only in acid soils and therefore acidity in this case is undesirable.

The blueberry thrives in soils so acid as to be worthless for ordinary agricultural purposes. Acidity also seems to be desirable for the cranberry and blackberry. The growth of leguminous plants is often affected in acid soils due to the lessened multiplication of the symbiotic nitrogen fixing bacteria.

More closely related to the growth of nut grass on acid soils is the work of the Rhode Island Experiment Station (4) in which they have studied the influence of different fertilizers on a number of grasses and mixtures for lawns, golf links and polo fields. These experiments, involving a number of grass plots, were started in 1905 and have now reached a point where by controlling soil reaction by varying the fertilizer practice they can definitely control not only the type of grass or clover but also assure freedom from many weeds. In other words, their experiments have yielded a method of weed control on lawns by fertilization. They have classified a number of grasses as follows: acid resistant, Awnless Brome, Red top, Rhode Island bent, Sweet Vernal, Tall meadow oat, Velvet grass; less resistant, Kentucky blue, Orchard, Meadow fox-tail, Sheep's fescue, Tall fescue, Timothy. This classification has been arrived at by planting mixtures in plots and applying residually acid, neutral and basic fertilizers for a period of 20 years.

Literature Cited

1. Wherry, E. T., 1920. Soil acidity—its nature, measurements and relation to plant distribution. In Ann. Rep. Smithsonian Inst., 1920, p. 247.

2. Atkins, W. R. G. Relation of hydrogen ion concentration of the soil and plant distribution. In Nature, 109, p. 80.

3. Gillespie, L. J. and Hurst, L. A. Hydrogen ion concentration measurements of soils of two types. In Soil Science 4, p. 313.

4. Hartwell, B. L. and Damon, S. C. The persistence of lawn and other grasses as influenced especially by the effect of manures on the degree of soil acidity. In Bul. 170 Rhode Island Experiment Station.

Oil Burning in Stationary Power Plants*

Steam and Mechanical Atomizing; Heating the Oil; Furnace Volume and Arrangement

(From a Paper Presented Before the A. S. M. E. by Nathan E. Lewis)

For moderate sized plants and where the load is reasonably steady, so that the boilers are not called on for extreme overloads, the steam atomizer is used and has certain advantages. At rated load, it operates with moderate draft; it is simple and easy to keep in repair; oil to supply it can be at lower pressure and temperature than for mechanical atomizers, 130 to 190 deg. F. and 40 to 60 lbs. It gives, however, a long, flat flame which must have room so that it will not touch the furnace walls or boiler heating surface; its capacity is 1,200 to 1,300 lbs. of oil an hour per burner, the maximum capacity to which the boiler can be worked being 200 per cent of rating; furnace volume required is but 0.15 cu. ft. per sq. ft. of heating surface or 0.35 cu. ft. per lb. of oil to be burned per hour. Air supply is through a false floor of brick checker work, the pattern and arrangement of this checker work having considerable influence on the effectiveness of the operation. This makes use of more than one row of burners impossible.

Mechanical atomizers are generally used where a heavy overload is to be carried and maximum capacities are desired. The mechanical burner will operate a boiler at as high overload as a coal-fired furnace; it will burn 1,500 to 1,600 lbs. of oil an hour and can go higher, if sufficient draft and blast are furnished; it gives a short conical flame and can evaporate as much as 10 lbs. of steam per square foot of heating surface and as much as 60 lbs. per cu. ft. of furnace volume. On the other hand, the oil should be heated to 200 to 280 deg., which requires live steam, and the oil is handled at 100 to 250 lbs. pressure; also a higher draft must be furnished than for steam atomization. Furnace volume must be provided of 0.5 cu. ft. per sq. ft. of heating surface or 0.5 cu. ft. per lb. of oil to be burned an hour. The high temperatures resulting from high rate of combustion make the problem of furnace wall maintenance difficult. Air is supplied around the burner itself, the position of the impeller plate through which the air comes having a considerable effect on the efficiency of the burner, but allowing of the use of two rows of burners in a boiler, staggered vertically.

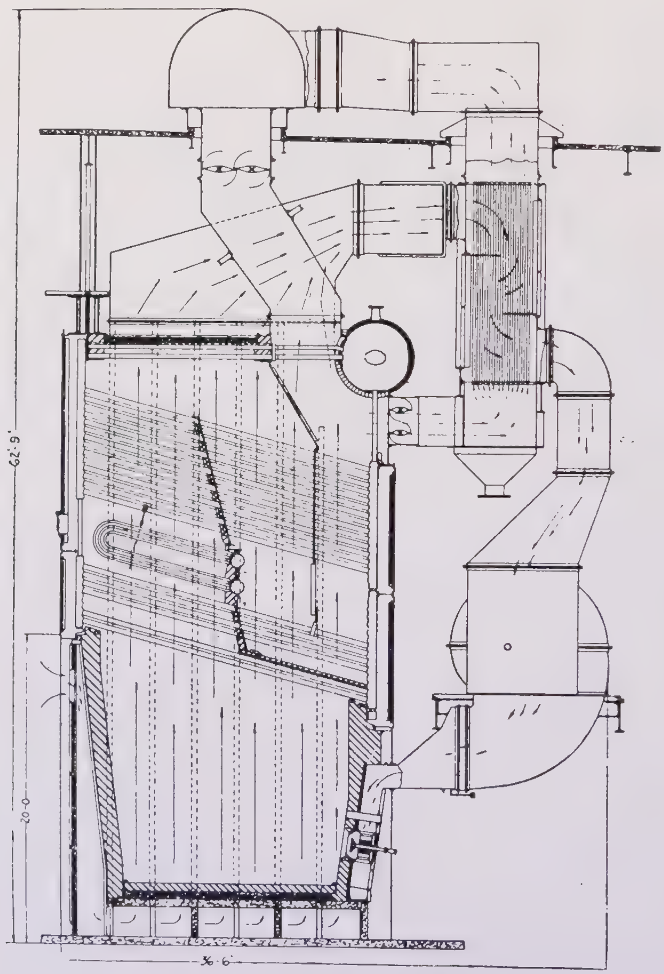
Oil Must Be Heated

In heating the oil, care should be taken that it is sufficient but not too great. Low temperature results in poor atomization and a smoky fire; too high temperature results in waste of steam, pulsations of the flame and a lowered capacity of the burner. With steam atomization, exhaust steam can be used for heating

* Power Plant Engineering, Volume XXIX, No. 2.

the oil and the heating apparatus need be tested only for 150 lbs. on the oil side and 60 lbs. on the steam side; for mechanical atomization, live steam is necessary for heating and both oil and steam sides of the heater should be tested for 250 lbs. The heavier the oil used, the higher the temperature to which it must be heated to work satisfactorily.

Extreme care must be taken to get pipe lines carrying oil tight, as the oil is difficult to hold at the joints and a small leak may produce a big fire hazard. It is necessary, therefore, to have the piping of ample size, to use long-radius bends and to keep the number of joints down to the least possible, providing valves to isolate sections for repairs when needed.



In this installation, walls are cooled by air and this air is further heated for supply to the oil burners.

Because of the high temperatures carried in oil-burning furnaces, it is essential to have the best possible furnace walls and to cool them as much as possible. Two methods of cooling have been proposed and tried: air circulation in hollow walls and setting boiler tubes in the walls to carry away some of the heat. Even

then, the best quality of fire brick is needed which can be had only by careful selection, this, of course, resulting in higher cost, though the quality of fire brick is being improved by manufacturers in response to the demand. Most brick will undergo plastic deformation under 25 lbs. pressure per sq. in. and 2,400 deg. F. temperature, or under 10 lbs. pressure and 2,600 deg. As furnace brick is often under 15 lbs. pressure and furnace temperatures run as high as 3,000 deg., it is evident that only the best brick will serve. Small volumetric changes in the brick, due to expansion and shrinkage, will result in bulged and cracked walls and larger changes, in spalling.

One form of air cooling which has been tried is shown in the illustration. it is an installation made by the Babcock & Wilcox Company for the Houston (Tex.) Lighting and Power Company. Air from a point about 17 ft. above the boiler room floor is passed down through ducts back of the rear wall of the furnace and under the floor to ducts back of the side walls. It rises through these and a breeching to an air heater whence it is drawn by a fan and delivered to the oil burners. This unit has 19,884 sq. ft. of heating surface, 11,660 sq. ft. of air heating surface, rated capacity of 150,000 lbs. of steam an hour and evaporation, at rating, of 7½ lbs. of steam an hour per sq. ft. of heating surface. The experience with this type of cooling is encouraging but not sufficient to warrant definite statements as to its economy.

(W. E. S.)

Sugar Prices

96° Centrifugals for the Period June 19, 1925, to September 15, 1925

Date	Per Pound	Per Ton	Remarks
June 19, 1925	4.40¢	$88.00	Cubas.
" 23	4.385	87.70	Cubas, 4.40; Philippines, 4.37.
" 24	4.37	87.40	Cubas.
" 25	4.33	86.60	Cubas.
" 26	4.285	85.70	Porto Ricos, 4.30, 4.27.
July 1	4.30	86.00	Porto Ricos.
" 6	4.285	85.70	Cubas, 4.30, 4.27.
" 7	4.27	85.40	Philippines.
" 9	4.255	85.10	Cubas, 4.27; Porto Ricos, 4.24.
" 10	4.21	84.20	Porto Ricos.
" 14	4.24	84.80	Cubas.
" 15	4.27	85.40	Cubas.
" 23	4.265	85.30	Cubas, 4.27; Philippines, 4.26.
" 24	4.27	85.40	Cubas.
" 27	4.24	84.80	Porto Ricos.
" 29	4.255	85.10	Porto Ricos, 4.27; Cubas, 4.24.
" 30	4.30	86.00	Cubas.
Aug. 3	4.27	85.40	Cubas.
" 4	4.30	86.00	Porto Ricos.
" 5	4.33	86.60	Cubas.
" 6	4.37	87.40	Spot Cubas.
" 7	4.385	87.70	Cubas, 4.37, 4.40.
" 10	4.37	87.40	Cubas.
" 11	4.35	87.00	Spot Cubas, 4.37, 4.33.
" 12	4.30	86.00	Spot Cubas.
" 14	4.32	86.40	Spot Cubas, 4.31, 4.33.
" 18	4.37	87.40	Cubas.
" 19	4.385	87.70	Spot Cubas, 4.37; Cubas, 4.40.
" 20	4.37	87.40	Cubas.
" 21	4.33	86.60	Cubas.
" 24	4.385	87.70	Spot Cubas, 4.38, 4.39.
" 25	4.40	88.00	Cubas.
" 28	4.415	88.30	Spot Cubas, 4.43; Cubas, 4.40.
Sept. 2	4.37	87.40	Cubas.
" 3	4.325	86.50	Cubas, 4.33; Spot Cubas, 4.32.
" 9	4.33	86.60	Porto Ricos.
" 14	4.27	85.40	Philippines.
" 15	4.21	84.20	Cubas.

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TABLE OF CONTENTS

INDEX TO VOLUME XXIX.

An asterisk preceding a page number indicates that the subject is illustrated.

Q

R

S

T

V

W

Y

ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXIX

JANUARY

Sugar cane tassels are kept fresh for pollinating purposes for several days by placing the cut stalk in a solution of sulphurous acid. Different strengths of solution are being compared here.